Water Monitoring and Assessment
Mode of Operations Manual
(MOMs)

Laboratory and Environmental Assessment Division (LEAD)

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MOMs
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Concurrences

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Preface

The purpose of the water monitoring Mode of Operations Manual (MOMs) is to describe the operations, procedures, equipment and methods used by the DEQ LEAD Water Monitoring and Assessment Sections. The reasons for doing this are:

1. To establish, document, and define the procedures upon which the Section operates;

2. To provide material to inform and instruct others who may come into the Section or operate as part of the Section; and

3. To provide material to inform others who are interested in the manner in which the Section operates.

It is anticipated that changes will be made frequently to this manual in order to reflect new and improved technology and approaches in water and biological monitoring and to reflect new program objectives. Please see the end of Chapter 1 for methods to revise and maintain MOMs.

MOMs is divided into five separate chapters each with its own table of contents:

(1) INTRODUCTION

(2) GENERAL CONSIDERATIONS

(3) FIELD SAMPLING METHODS

(4) FIELD ANALYTICAL METHODS

(5) **CONTINUOUS MONITORING METHODS**.

In its entirety, MOMs is primarily useful to new and current Section staff members. However, parts of it, especially the third, fourth and fifth chapters will be useful to those interested in the methods used to obtain the data or to those assisting the Section in sample collection. In addition, those interested in data quality, management, and analysis will be interested in the second and fifth chapters.

MOMs is the official documentation for all water monitoring and assessment Standard Operating Procedures (SOP), referenced in various Quality Assurance Project Plans. Changes to MOMs must be reviewed and approved by the Water Monitoring and Assessment Section Managers, Quality Assurance Officer(s), and Laboratory Division Administrator prior to their insertion. The DEQ Laboratory SOP for Document Control (DEQ02-LAB-0004-SOP) describes the process for updating MOMs. Contact the DEQ QA Officer for more information.

DISCLAIMER: The use of brand, trade, or firm names in MOMs is for identification purposes only and does not constitute endorsement by Oregon Department of Environmental Quality.

Front Cover Illustrations

Top left: Dennis Ades demonstrates the two-bucket technique for surface water grab sampling from the Lower Bridge over the Deschutes River.

Top right: Larry Whitney prepares to measure width, depth, and flow for the Upper Grande Ronde Best Management Practices Long-Term Monitoring Program.

Bottom: Steve Mrazik shows that sample filtering is fun!

Chapter 1 – Introduction

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Purpose

An effective water quality management program must be based upon an accurate and complete understanding of water quality conditions within the state. Water monitoring and assessment are the foundations for sound water quality management. The Oregon DEQ water monitoring and assessment strategy is based upon providing reliable, high quality water quality information that will address the short term and long term information needs of the data users.

The Mode of Operations Manual (MOMs) is intended to be the reference documentation of the Water Monitoring and Assessment (WMA) Sections' Sampling and Analytical Method SOPs, as well as other general monitoring considerations and guidelines. The contents of this document were developed by the MOMs Committee, reviewed by laboratory staff, and approved by the WMA Section Managers, the DEQ QA Officer, and the Lab Division Administrator. This Chapter provides a summary of the Water Monitoring and Assessment activities and describes how the sections operate within DEQ.

Definitions

Water Quality

For the purposes of this manual, water quality is defined as the summation of chemical, physical, and biological quality of the waters of the state.

Waters of the State

"Waters of the State" include lakes, bays, ponds, impounding reservoirs, springs, wells, rivers, streams, creeks, estuaries, marshes, inlets, canals, the Pacific Ocean within the territorial limits of the State of Oregon, and all other bodies of surface or underground waters, natural or artificial, inland or coastal, fresh or salt, public or private (except those private waters which do not combine or effect a junction with natural surface or underground waters), which are wholly or partially within or bordering the state or within its jurisdiction (Oregon Administrative Rule 340-041-0006 (14)).

Water Quality Indicators

It is not practical or feasible to test for all possible components of water quality. Water quality indicators are selected to represent broader categories of impairment. Overall water quality is assessed by collecting data on indicators. Indicators commonly used by DEQ are categorized below.

CHEMICAL

Nutrients, chlorophyll, pH, alkalinity, dissolved oxygen, oxygen demand (BOD, COD, TOC, TOX), common ions, metals, pesticides, PAHs, PCBs, volatile and semi-volatile organic compounds

PHYSICAL

Temperature, turbidity, total solids, suspended solids

BIOLOGICAL

Aquatic populations (Bacteria, algae, macroinvertebrates, fish)

HABITAT AND HYDROLOGY

While the aquatic habitat may not be considered a direct indicator of water quality, habitat and water quality are inextricably linked with the beneficial use of the water. Habitat and hydrology characteristics are often included as part of water quality assessments. Examples of these characteristics include: shade, channel width and depth, pool and riffle count, bottom substrate type, large woody debris, flow.

Sample Matrices

Water quality investigations often include the sampling and analysis of not only water samples, but also the other components of the aquatic environment: tissue and sediments.

Data Users

While the DEQ Water Quality Management Program is the immediate customer for DEQ WMA programs, the public is the ultimate customer. The objective is to provide information that can answer basic questions. This will lead to an informed public and will help achieve wise water quality management policies. In addition to the general public there are many more specific data users: elected officials, environmental organizations, trade organizations, industry, education, public health agencies, land use management agencies, fish and wildlife organizations and agencies, permit writers, and Total Maximum Daily Load (TMDL) modelers.

Each of these groups will have their own specific questions and data needs. These basic questions include:

- Is water quality changing? If so, by how much, and where?
- How does water quality vary spatially across the state?
- Does water quality meet standards?
- What pollutants are affecting water quality?

Relevant Laws and Regulations

The direction of most of DEQ's Programs comes from various Federal and State Laws and Regulations. While full knowledge of these laws and regulations is not necessary, a basic awareness of the pertinent laws and regulations and their contents is useful for work in the WMA Sections, and for advancing one's career in work related to water quality management.

The primary federal laws driving water quality sampling are PL 92-500 and PL 95-217, the Federal Water Pollution Control Act Amendments of 1972 and the Clean Water Act of 1977, respectively. In addition, the Resource Conservation and Recovery Act (RCRA) of 1976 and the amendments (42 U.S.C. section 6901 et seq.) added by the Solid Waste Disposal Act of 1980

combine to mandate protection of human health and the environment from hazardous waste disposal practices. These Acts are responsible for a large proportion of the Water Quality Program's funding and provide a framework for the USEPA and State Agreement.

EPA references used extensively in developing the water quality standards are Quality Criteria for Water 1976 (The Red Book), and Quality Criteria for Water 1986 (The Gold Book), and Water Quality Standards: Criteria Summaries (440 Series).

The Oregon Environmental Quality Commission (EQC) authorizes Oregon DEQ Water Quality Program rules. The rules are codified in Oregon Administrative Rules (OAR) Chapter 340 by the Oregon Secretary of State. The EQC has adopted these rules under the authority of Oregon Revised Statutes, Chapter 468B.

The sections of OAR Chapter 340 most related to Water Monitoring and Assessment activities are found under Divisions 40 and 41. Division 40, “Groundwater Quality Protection”, establishes the mandatory minimum groundwater quality protection requirements. Division 41, “Statewide Water Quality Management Plan: Beneficial Uses, Policies, Standards, and Treatment Criteria for Oregon”, contains the beneficial uses and water quality standards for all major river basins in Oregon. These standards establish limits for various parameters required to support recognized beneficial uses of the water. These limits or concentrations should be known in order that an individual can be aware of potential problems (i.e. problem areas, problematic practices, or problems with the Standards).

Division 61 discusses Solid Waste Management in general. It should be noted that the Solid Waste Program relies on the Water Quality Standards to determine adverse impacts. Division 100 contains the rules regulating hazardous waste management.

Summary of Specific Monitoring Programs

Rivers and streams

Watershed assessment of rivers and streams in Oregon is a high priority and receives the bulk of monitoring resources. An annual prioritization of monitoring activities is carried out in conjunction with the appropriate programs and regions. A combination of monitoring programs and approaches are used for rivers to help address information needs. These are summarized below.

Ambient River Monitoring Network

A statewide network is sampled to provide conventional pollutant data for trending, standard compliance, and problem identification. Some sites have been monitored since the late 1940’s. Sites were selected to represent all major rivers in the state and provide statewide geographical representation. Sites are primarily integrator sites; they reflect the integrated water quality impacts from point and nonpoint source activities as well as the natural geological, hydrological and biological impacts on water quality for the watershed that they represent. Larger river basins have multiple sites, which may be based upon tributaries, land use changes, topographical

changes, ecoregions, point sources, and nonpoint sources. Sampling frequency is based upon resources, priorities, and statistical needs for trending, and determining central tendency and data distribution characteristics.

Watershed TMDL Assessments

The Department conducts extensive assessments to provide a detailed characterization of water quality conditions and to determine cause-and-effect relationships at the watershed level. Most watershed assessments are conducted for the purpose of developing Total Maximum Daily Loads (TMDLs) as required by the Clean Water Act for streams that do not meet water quality standards (water quality limited). These assessments usually take several years and include elements to characterize the hydrology (flow), chemistry, physical, and biological conditions of the watershed. The studies involve synoptic sampling surveys to characterize spatial variability and seasonal and diel studies to characterize seasonal and diel variability. Data is typically used to develop mathematical models used to establish the TMDLs.

Mixing Zone Studies

Mixing zone studies are intensive surveys that are conducted where point sources discharge to streams. They may include chemical, physical, and biological assessment. The purpose of these studies is to characterize impacts on the receiving streams and compliance with water quality standards and permit conditions.

Use Attainability Surveys

These studies focus on stream segments that contain multiple point and/or non-point sources and have either poor water quality or the potential for deterioration of water quality. Segments for study are prioritized by water quality program staff with input from regional and laboratory staff. The studies identify and evaluate existing and potential beneficial uses and determine if these uses are being impaired. Intensive planning and collection of background information and biological, chemical and physical field data may be required to fulfill the study objectives. Recommendations for best management plans or changes in recognized beneficial uses may be made.

Groundwater

Groundwater assessments conducted by DEQ WMA sections are one of three kinds; ambient groundwater assessment; Groundwater Management Area (GWMA) characterization study, or long term trending network.

Ambient groundwater assessments are one-time assessments of geographic regions where vulnerability to groundwater contamination exists from land use practices and/or nonpoint source activities. These assessments generally cover an area of from 50 to 400 square miles and involve sampling from 20 to 80 wells for an extensive suite of inorganic and organic constituents. Pesticide scans for pesticides used in the area are included.

The Department has conducted 45 regional groundwater studies since 1985. Some evidence of groundwater contamination has been detected in 26 of the 45 areas studied. The most common contaminant is nitrate, followed by: pesticides, volatile organic compounds, and bacteria. Many areas have a high percentage of the wells exceeding the drinking water standard for nitrates. Recent studies have been conducted in the Milton-Freewater area and the Upper Willamette Valley.

Because of those regional groundwater studies, two areas have been declared Groundwater Management Areas (GWMAs) under the Groundwater Quality Protection Act: northeast Malheur County and lower Umatilla Basin. Long term trending networks of 40 wells each are maintained in the Lower Umatilla and Malheur County Groundwater Management areas. Wells are sampled six times per year for nitrates and pesticides. Trending analysis of the data is conducted using a Seasonal-Kendall Test to determine long-term trends and the effectiveness of the GWMA management plan.

Estuaries

Estuarine TMDL assessment studies have included chemical, biological, bacterial, flow and mixing, temperature and continuous monitoring. Special studies have been completed to address toxic concerns related to tributyltin (TBT), PAHs and metals. Coos Bay has a shellfish consumption advisory posted for certain areas because of TBT contamination in shellfish tissue.

The Western Pilot Coastal Environmental Monitoring and Assessment Program (CEMAP) assesses estuary health through probabilistic sampling. The sampling includes water quality, sediment toxins, fish tissue toxins, benthic infauna, and fish and plant species enumeration.

Estuary shellfish sanitation monitoring is conducted in cooperation with the Oregon Department of Agriculture, which administers the shellfish sanitation program for Oregon. The following bays receive monthly monitoring for bacteria as required by U.S. Food and Drug Administration requirements for the shellfish growing areas: Tillamook, Yaquina, Umpqua, Coos, Nehalem, and Netarts.

Lakes

Lake monitoring is typically conducted by DEQ for the purpose of developing TMDLs and for monitoring special conditions, such as toxic algal blooms. Some lake monitoring is done in support of local watershed or lake protection organizations and in support of the Citizen Lake Watch program that is administered by Portland State University.

Wetlands

Routine wetland monitoring is not conducted by the DEQ. Some wetland monitoring may be done as part of a watershed assessment or in response to complaints.

Ocean

CEMAP assesses near-coastal water health through probabilistic sampling. Sampling occurs in 30 to 120 meters of water and includes water quality, sediment toxins, fish tissue toxins and benthic infauna.

DEQ conducts beach monitoring for bacteria levels under the BEACHES program in conjunction with the Oregon Department of Human Services (DHS). DHS notifies the public and issues advisories or beach closures when bacteria levels are unsafe for contact recreation.

The Oregon Department of Agriculture conducts beach monitoring for Paralytic Shellfish Poisoning, as well as for bacteria levels, and issues harvest closures when shellfish are unsafe for consumption.

Biomonitoring

Biomonitoring integrates the physical, chemical, and biological elements and processes of streams and rivers to assess the overall ecological integrity of water resources. The evaluation of stream integrity or impairment is based on comparing species observed at a stream with the assemblage of species that would be expected at a group of comparable reference streams that has minimal human impairment. A range of species assemblages can be used for stream assessments including macroinvertebrates, fish and amphibians, and periphyton. Ecological data can be complex and rich in details. Multivariate and multimetric tools are used to assess stream ecological integrity relative to reference condition.

Sampling strategies typically used in biomonitoring studies include:

- Regional status and trends assessments using probabilistically selected sites.
- Reference condition assessments that look for the streams and basins with the least human impairment available.
- Restoration or management effectiveness.
- Special studies of point source and non-point source pollution.
- Development and implementation of numeric biocriteria.

Toxics

These studies focus on the collection of water, sediment, or fish tissue for analysis of the presence and concentration of various toxins, e.g., pesticides, heavy metals, and persistent bioaccumulative toxins (PBTs). Various biotas are tested for chronic and acute toxicity from waste streams or polluted water bodies.

Solid/Hazardous Waste Site Monitoring

Periodic monitoring is carried out at permitted solid/hazardous waste sites (often as part of a permit requirement). Split sampling and a review of field monitoring and analytical techniques is carried out, with the permittee's contracted monitoring organization, in order to gain an estimate of data quality as reported to DEQ.

Complaint Investigation and Enforcement

When the Department becomes aware of a potential water quality problem from an activity or illegal discharge, a water quality investigation may be conducted to document the extent of the problem. If the information from the investigation warrants, appropriate enforcement action is taken including civil or criminal penalties and compliance orders.

Investigative Monitoring

The objective is to define cause/effect relationships and/or provide further data to support priority agency work in developing solutions to a problem (e.g., construction grant activities, permit renewal, rule changes, standards, etc.). These studies require careful planning to gain good understanding of the system being studied. They usually involve a large commitment of personnel over a short period of time.

Cooperative (Interagency) Surveys

The purpose of these surveys is to coordinate monitoring activities and resource commitments between agencies to gain useful data with efficient use of resources.

Volunteer Monitoring

Volunteer monitoring through watersheds groups and other organizations is an expanding field for the collection of water quality data. The Department provides monitoring equipment, training, technical assistance, and data management for volunteer monitoring groups. A data quality matrix has been developed to assign data quality levels and appropriate uses for volunteer monitoring data. A Volunteer Monitoring Coordinator provides full-time assistance to watershed councils and other volunteer monitoring groups.

Sampling Priorities

Ideally, the purpose of the WMA sections is to provide the data user with timely and useful data of known quality in an understandable fashion. However, potential conflicts may occur when time and resources are scarce. Therefore, priorities need to be established. While each monitoring situation is unique and must be assessed, the following are generalized priorities for monitoring:

Top priority shall be given to data collection that is needed because the safety, health or well being of the citizens of Oregon is at risk (e.g. pesticide spill).

At no time should the safety of the individual be placed at risk (e.g., exposure to toxins without taking proper precautions). Staff should refer to all applicable Job Safety Assessments (JSA).

At no time should data be collected where data quality is sacrificed unless specifically stated on the data sheet and in the QA implementation plan. Extreme care should be given to insure sample and data integrity. This includes collecting a representative sample, properly handling and preserving the sample, verifying data entered into a computer and following all quality control procedures.

Data should not be collected without a specified use for that data. Normally, use of the data and technical assistance is given equal priority to the collection of the data.

Collection of data is given a higher priority than use of the data (e.g. data reports) only when conditions for data collection are unique (e.g. drought); health, safety or welfare is at stake; or new programmatic decisions to do so have been made (e.g. dropping routine data reports so that biennial assessments can be made or special projects undertaken).

MOMs Document Control

The DEQ Laboratory SOP for Document Control (DEQ02-LAB-0004-SOP) describes the process for updating MOMs. Contact the DEQ QA Officer for more information. That procedure is summarized and paraphrased below.

When deemed necessary by section(s), or QA staff or management; and in consultation at meeting held by WMA sections; the MOMs Coordinator shall revise MOMs. Method changes or additions are considered major revisions. For a major revision of MOMs, a MOMs Committee may be formed. The MOMs Committee develops and produces the contents of MOMs with the assistance of the MOMs Committee Coordinator and the guidance of the WA and WQM Section

Managers. The version of the document will increment to the left of the decimal place (e.g., 2.1 to 3.1).

Routine, typographical or word-smithing changes are considered minor revisions. The version of the document will increment to the right of the decimal place (3.2 to 3.3). The MOMs Coordinator will update the text and document revisions as necessary.

Beginning with version 3.2, a section has been added at the end of the Introduction that describes changes to the separate section will be added to the end of MOMs that lists all of the significant changes made for each version. Each section in the chapter may be updated individually are the entire chapter may be updated. In either case, the dates in the header reflect the dates when specific changes were made. This will aid signatories in reviewing changes made to MOMs and make it easier to track changes from version to version.

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Document Revision History

3/10/2009 – changes from 3/1/2004

Entire Document

A generic Water Monitoring and Assessment (WMA) reference was created to generically incorporate both Watershed Assessment and Water Quality Monitoring sections in LEAD. The Title was also updated to reflect this. General formatting was revised for all of the sections to add flexibility for easier maintenance of the document. Hyperlinks were updated where possible. A table of contents was added to each section to help find information faster. The date in the header for each section will reflect the date that the specific section was updated.

Chapter 1 - Introduction

References to LEAD were added and the address was updated on the cover page. The concurrences were changed to reflect current staff and positions. A hyperlink was added to the Document Control SOP.

Chapter 2 – General Considerations

The Data Quality Matrix table was moved to the end as an appendix of the section rather than being imbedded in the middle of the text. The Temperature P/A criteria in the Data Quality Matrix was changed to $\pm$ 0.5^{o}C and the Turbidity criteria was updated to allow $\pm$ 1 NTU for values below 20. A hyperlink to the controlled version of the Data Quality Matrix was added. The hyperlink link to the LASAR program on the web was updated. There were several references to the lab at PSU, those have been updated to reflect the current facility.

Chapter 3 – Field Collection Methods

> ***Surface Water Sampling***: Corrected supplies and procedure for Chlorophyll sampling to use 0.7 micron glass fiber filter.

Chapter 4 – Field Analytical Methods

> ***Conductivity and Salinity***: The procedure for the annual temperature compensation check for the YSI Model 30 was updated to reflect current practices.

Chapter 5 – Continuos Monitoring Methods

> ***Datasonde***: Updated the hyperlink link and reference to USGS guidance document.
>
> ***Continuous Monitoring Data Quality Assurance***: Removed copy of Data Quality Matrix from this section since there is already a copy in Chapter 2. Inserted hyperlink to the QNet controlled copy of the Data Quality Matrix and referred reader to Appendix A of Chapter 2. Updated some of the hyperlinks where they existed.

CHAPTER 2 – GENERAL CONSIDERATIONS

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QUALITY ASSURANCE

Quality assurance (QA) is a top priority for DEQ monitoring programs because the data collected are used in regulatory and management decisions. The QA procedures followed in the monitoring sections are intended to produce data of known quality appropriate to the intended use. The DEQ Laboratory implements a full quality assurance program with internal and external elements. Details of DEQ's quality assurance program may be found in the following documents: DEQ Agency Quality Management Plan (QMP), DEQ Laboratory Quality Assurance Plan, and DEQ Field Sampling Reference Guide (FSRG). Consult these documents for the most current information regarding QA at DEQ. Contact the DEQ QA Officer for more information. Individual monitoring projects may have different or additional QA requirements, which will be documented in the appropriate Quality Assurance Project Plan (QAPP).

Analytical data can only be as reliable as the sample analyzed. As stated in the FSRG, the laboratory must assume representativeness, which is "that everything in the sample container constitutes the sample, that the sample was collected and preserved properly, and that it does not contain extraneous contamination." Chapter VII of the FSRG explains the information the laboratory requires in order to analyze a sample and report its unqualified results.

The MOMs manual is an important part of the LEAD quality assurance program. MOMs documents the Standard Operating Procedures (SOPs) used in the field, serves as a training document for new staff, and provide regularly updated reference material for experienced staff. When documented procedures in MOMs are followed by all staff, data is collected and reported consistently.

This chapter is only an overview of field QA procedures, and a general description of what is necessary to deliver representative samples to a laboratory. The following chapter (Project Planning) describes QA tools needed to plan and document quality decisions at the project level. Sections on sampling methods (Chapter 3), analytical measurements (Chapter 4), and continuous monitoring methods (Chapter 5) contain specific quality control instructions.

Data Quality Objectives

Each project for which data is collected should have clearly defined Data Quality Objectives (DQOs). DQOs are the quantitative and qualitative statements describing the quality of data needed to support a specific decision or action. The five parameters commonly used to judge data quality are (also described in Section 6 of the Quality Assurance Manual):

- Precision
- Accuracy
- Representativeness
- Comparability
- Completeness

Precision

Precision is a measure of the reproducibility of the result and depends on how well we can compensate for random errors, such as instrumental error or sample variation. One way to measure precision is to collect and analyze duplicate samples. Duplicate samples are collected as independent samples using the same sampling procedures (e.g. separate grab samples with a bailer or adjacent core samples of soils). A duplicate field sample can consist of two samples

collected at the same time (as in water quality sampling), or a repeated procedure in the same location (as in macroinvertebrate sampling or a flow measurement). The variability in the results obtained from duplicate samples is a sum of the sampling and analytical variability and variability inherent in the sample (we assume representativeness but samples have proven to be heterogeneous). This variability is the most meaningful measure of uncertainty in the individual samples obtained.

When measuring a water quality duplicate, each measurement is repeated on the duplicate sample, and a duplicate is sent in to the laboratory for each analysis. Staff should take duplicate samples or measurements at 10% of sample locations, or at least once during a sampling expedition, whichever number is greater. For example, if a sampling expedition includes only three sites, a duplicate should be collected at one of those locations. If field measurements of the duplicate sample do not agree with those of the "primary" sample, reanalyze the duplicate (and/or primary) sample to confirm or deny the disagreement in results. Note the re-measurement(s) on the field data sheet; do not cross out the original results.

A sampling expedition is a field event that groups environmental samples or observations that are collected for a specific purpose. A sampling expedition may span the course of a day or several days, or, in the case of long-term continuous monitoring, an entire season.

Accuracy

Accuracy is a measure of how close the measured value is to the true value and depends on how well we can control systematic errors, such as faulty equipment calibration or observer bias. Increasingly, however, some scientists, especially those involved with statistical analysis of measurement data, have begun to use the term "bias" to reflect this error in the measurement system and to use "accuracy" as indicating both the degree of precision and bias (see **Figure 1**). For the purpose of this document, the term "accuracy" will be used to encompass "bias".

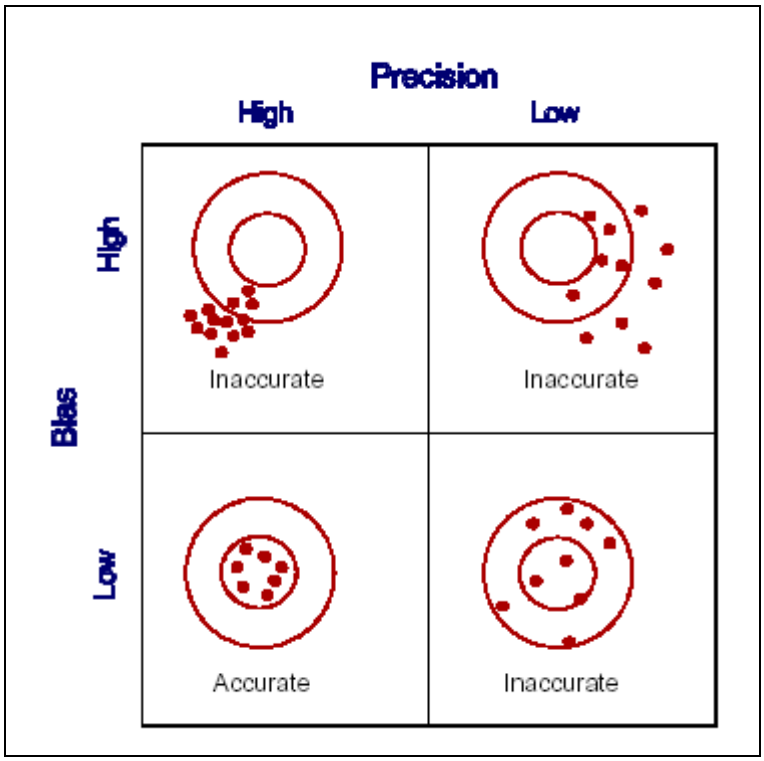
Procedures to insure accuracy are described in Chapters 3, 4, and 5. As an example, accuracy can be assured by instrument calibration and comparisons with external standards. Accuracy can also be gauged by an independent measurement such as a contracted laboratory identification of macroinvertebrate samples first identified in-house.

Accuracy can also be assessed by analyzing "blank" samples. This verifies that the measured or analyzed value is true and not influenced by the sampling method or equipment. One equipment blank sample should be submitted for each sampling expedition. Blank water should be drawn from the sinks equipped with deionizing system taps in the laboratory. Volatile organic compound (VOC)-free water, available in the organic laboratory, should be used for blanks for VOC analyses. Blank water should be processed and transported exactly as are regular samples. All field water quality measurements except dissolved oxygen should be performed on blank samples.

Representativeness

Collecting a sample representative of the true environmental conditions requires proper sampling, handling, preservation, and transport. Refer to Chapters 3 and 4 for specific sample collection procedures and field analyses. Refer to the FSRG for required containers, volumes, preservation, blanks, and holding times for specific analyses. Sample representativeness is also discussed in Chapter VIII (Sample Collection) of the FSRG.

Figure 1: Precision, Bias, and Accuracy



Comparability

Data comparability is essential to interpret results from samples collected at different times and locations. Carefully following documented procedures is one of the most important steps in maintaining data comparability. Use approved EPA methods whenever possible. Refer to Chapters 3, 4, and 5 for guidance on specific procedures and analyses.

Completeness

Completeness of a study is based on a comparison of the amount of valid data expected and the amount actually generated from the study. Before a project begins, the project manager or data user should decide how much data are needed to answer the project questions and what is the minimum percentage of expected data that will be useable. While there are no specific QA procedures to assure project completeness, following a QA program will increase completeness by lessening the amount of data discarded for insufficient certainty. It may also be appropriate to budget a small amount of oversampling if there is an expected or assumed rate of incompleteness.

Data Quality Matrix

Data generated from the laboratory is graded based on its quality, Levels A+ through F. These criteria are summarized for field water quality parameters in the Data Quality Matrix (See **APPENDIX A** at the end of this Chapter). The most current version can be found on QNet or by clicking on this hyperlink DEQ04-LAB-0003-QAG). Data Quality Matrix Limits should be defined in applicable QAPP. Data quality also depends on other factors as described in a QAPP, as discussed in Chapter 2, Project Planning.

Documentation

The quality of data often depends not on the analysis, collection, or measurement, but the documentation that accompanies (or doesn't accompany) the sample. Obvious examples are sample location, time, date, and required analyses. The FSRG details required documentation such as Request for Analysis forms and non-routine documentation such as chains-of-custody. For routine ambient water quality sampling, measurements are only recorded on field data sheets for the DEQ Lab and the Public Health Lab (for microbiological samples). Bound field notebooks are kept for projects and this allows sampling events to be reconstructed and documentation of additional metadata that have no place on the field sheets. All documentation should be in ink. Corrections should be made by drawing a single line through the mistake, writing in the correction, and initialing the correction. Documentation of weather conditions and all anomalous conditions, such as extremely high or low flow or bulldozers in the stream, will assist in data interpretation.

Following the concepts outlined in this section, as well as the remaining documentation in MOMs and other referenced material, assures that data becomes high quality information. Remember that the samples we collect will be used to inform decision-makers and to educate the public.

References

Oregon DEQ, December 1997. State of Oregon DEQ Quality Assurance Management Plan, Oregon DEQ Laboratory, Portland, Oregon.

Oregon DEQ, July 1998. DEQ Laboratory Quality Assurance Plan, Oregon DEQ Laboratory, Portland, Oregon.

Oregon DEQ, December 1998. DEQ Field Sampling Reference Guide, Oregon DEQ Laboratory, Portland, Oregon.

Oregon DEQ, February 2004. Data Quality Matrix Version 3.0, DEQ04-LAB-0003-GD, Oregon DEQ Laboratory, Portland, Oregon.

Oregon DEQ, State of Oregon DEQ Quality Management Plan, Oregon DEQ Laboratory, Portland, Oregon. DEQ03-LAB-0006-QMP.

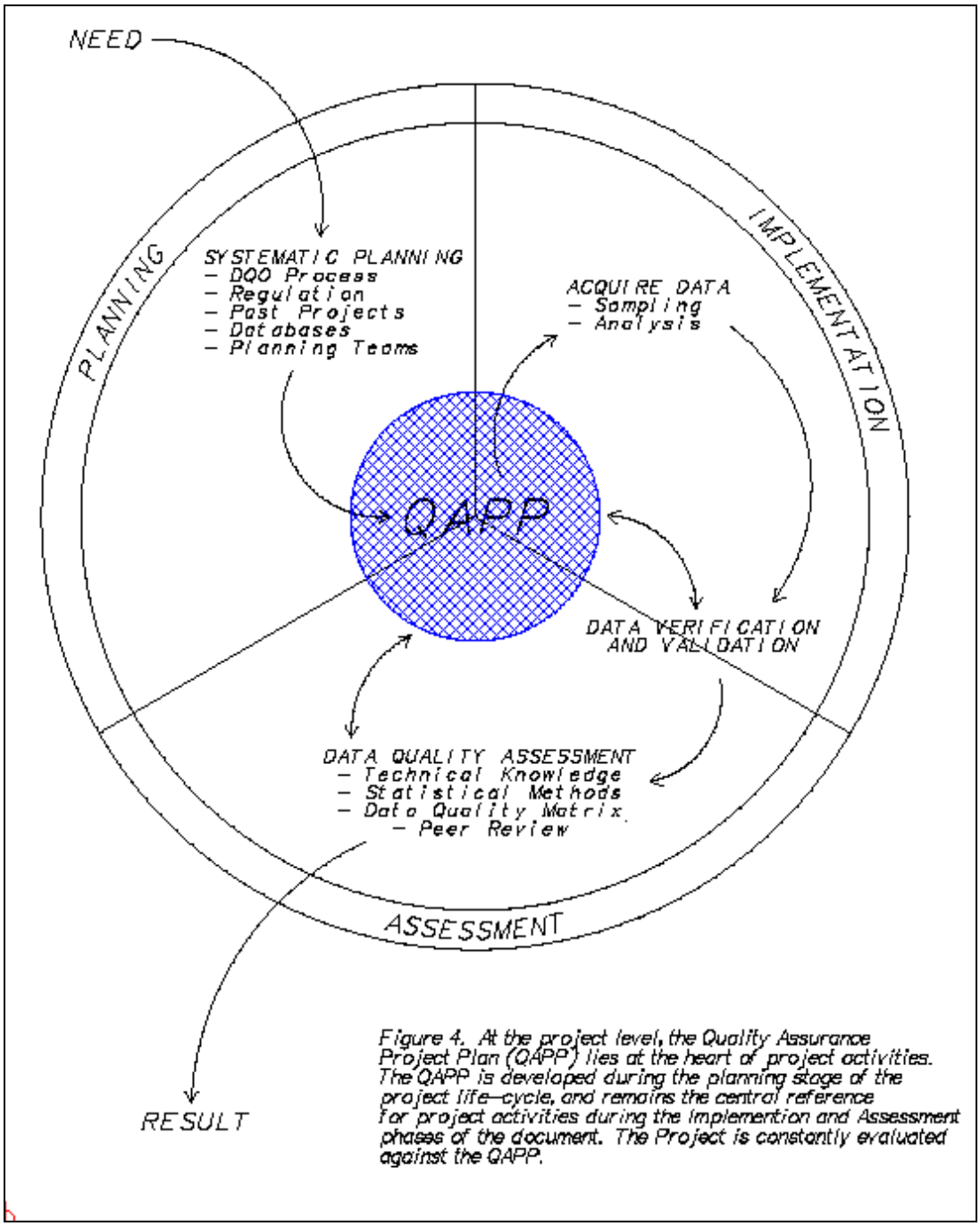
US EPA, Office of Wetlands, Oceans, and Watersheds, September 1996. The Volunteer Monitor's Guide to Quality Assurance Project Plans. EPA 841-B-96-003. Washington, DC.

PROJECT PLANNING

The DEQ Quality Management Plan (QMP) describes the use of Quality Assurance Project Plans and Sampling and Analysis Plans within DEQ.

Projects within DEQ that generate, acquire, and use environmental data follow a generic three-step life-cycle: (1) planning; (2) implementation and oversight; and (3) assessment and improvement (**Figure 2**).

Figure 2 DEQ Project Life-cycle (from QMP, Figure 4)


NEED
PLANNING
SYSTEMATIC PLANNING
– DQO Process
– Regulation
– Past Projects
– Databases
– Planning Teams
IMPLEMENTATION
ACQUIRE DATA
– Sampling
– Analysis
QAPP
DATA VERIFICATION
AND VALIDATION
DATA QUALITY ASSESSMENT
– Technical Knowledge
– Statistical Methods
– Data Quality Matrix
– Peer Review
ASSESSMENT
RESULT
Figure 4. At the project level, the Quality Assurance Project Plan (QAPP) lies at the heart of project activities. The QAPP is developed during the planning stage of the project life-cycle, and remains the central reference for project activities during the implementation and Assessment phases of the document. The Project is constantly evaluated against the QAPP.

Careful attention to quality issues at each stage in the life-cycle is crucial for ensuring that project data is of the quality required for informed decision making. Moreover, the project life-cycle is iterative in nature, feeding valuable quality information back into itself and other projects for constant system improvement. The scope of this simplified project model applies to all environmental monitoring and measurement activities mandated by State or Federal Regulations, or memoranda, and includes environmental data generated both internally and externally by activities conducted through Agency programs, contracts, inter-agency agreements, grants, and cooperative agreements.

Quality assurance at the project level is a dynamic system in which two basic elements--quality control and quality assessment--form a positive feedback loop. Once a project's data quality objectives (DQO's) are defined during planning, effective operation of the Quality System requires that quality control procedures are integrated into the overall data generation process. See the previous chapter on Quality Assurance for a further discussion of data quality objectives. The QC data are then used to decide whether the desired data quality objectives are being achieved and, if not, to establish a basis for any corrective actions that may be needed. To assure that these activities are a routine part of all data collection efforts, all environmental monitoring and measurement activities within the scope of the Quality Management Plan **must** be defined in a Quality Assurance Project Plan (QAPP).

Quality Assurance Project Plans

The Quality Assurance Project Plan (QAPP) is the core project level component in the Quality System and, consequently, is a ***required*** element. The QAPP integrates all technical and quality aspects of a project, including planning, implementation, and assessment. The purpose of the QAPP is to systematically document project activities and provide a defined plan for obtaining the type and quality of environmental data needed for a specific decision or use. The QAPP documents how quality assurance (QA) and quality control (QC) activities are applied to ensure that project results are of the type and quality needed for the intended use of the data. The QAPP addresses all monitoring operations, including field and laboratory activities, which generate data, as well as data storage, retrieval, and assessment. QAPPs must be written for all DEQ projects regardless of whether or not data is generated internally within DEQ or externally from third-parties or partners outside the Agency. DEQ's requirements for QAPPs are equivalent to those required by EPA. The elements of the QAPP fall within four major project categories:

(1) Project Management;
(2) Data Generation and Acquisition;
(3) Assessment and Oversight; and
(4) Data Validation and Usability.

A number of specific elements must be addressed in the QAPP to fully document the project's planned activities. The minimum elements that must be addressed in the QAPP include:

(1) Project Management Elements:
- Title and Approval Sheet
- Table of Contents
- Distribution List
- Project/Task Organization
- Problem Definition/Background
- Project/Task Description
- Quality Objectives and Criteria
- Special Training/Certification
- Documents and Records

(2) Data Generation and Acquisition Elements:
- Sampling Process Design
- Sampling Methods
- Sample Handling and Custody
- Analytical Methods
- Quality Control
- Instrument/Equipment testing, Inspection, and Maintenance
- Instrument/Equipment Calibration and Frequency
- Inspection/Acceptance of Supplies and Consumables
- Non-direct Measurements
- Data Management

(3) Assessment and Oversight Elements:
- Assessments and Response Actions
- Reports to Management

(4) Data Validation and Usability Elements:
- Data Review, Verification, and Validation
- Verification and Validation Methods
- Reconciliation with User Requirements

Complete details on QAPP requirements can be found in *EPA QA/R-5 EPA Requirements for Quality Assurance Project Plans* (US EPA, 2001). Copies of this document are available from the EPA web site and the DEQ intranet. DEQ-specific guidance on the development and writing of QAPPs is in development and will be posted to Q-net when it becomes available. All Agency QAPPs must be reviewed by the QA Officer (QAO) or designee. Individual divisions and offices within the Agency are responsible for ensuring that all QAPPs are approved *prior* to the commencement of any work and that project activities are implemented as documented. Individual division and offices are responsible for maintaining copies of the approved QAPPs. However, electronic copies of all approved QAPPs should be submitted to the QAO (preferably in PDF format), who will maintain a library of QAPPs and post electronic copies to the DEQ internet.

Sampling and Analysis Plans

In many cases a generic QAPP may be written that covers many DEQ projects/activities where only specific details (e.g., sampling locations, measurement parameters, etc.) change. For these projects, abbreviated Sampling and Analysis Plans (SAPs) may be substituted in lieu of a complete new QAPP. However, the SAP must reference the parent QAPP and may not make substantial changes to the DQOs established in the parent document. The use of a SAP in lieu of a QAPP is valid for data that is generated internally within the Agency only. All projects involving data generated from external or secondary sources must be documented in a QAPP.

SAPs should be used only to specify changes in sampling location and monitoring data. If additions or deletions to a project's monitoring requirements are such that the QA or QC activities documented in the parent QAPP are compromised, a new QAPP must be written and approved. SAPs must be submitted to and approved by a QAC prior to the commencement of any project work. It the responsibility of the originating division and/or office to ensure that the requirements specified in the QAPP are satisfied. Electronic copies of SAPs should be submitted to the QAO, who will maintain a library of SAPs with the parent QAPPs and post them to the internet.

Analysis Request Forms

All planned sampling events of any size must be documented using an Analysis Request Form before sampling occurs. These Analysis Request Forms provide the laboratory a list of sample quantity, sample media, requested analyses, date of sampling and delivery, QA samples required, and requested date for data reporting. An Analysis Request Form also identifies the project manager, their telephone number, and fund code to which sample analysis should be charged. See the "Sample Collection Activity Meta-Data" portion of the following "Data Management" section for a discussion of required data elements.

References

Oregon DEQ, DEQ Quality Management Plan, Version 4.1, DEQ03-LAB-0006-QMP Oregon DEQ Laboratory, Portland, Oregon.

US EPA, 2001. EPA Requirements for Quality Assurance Project Plans (EPA QA/R-5). EPA/240/B-01/003, Office of Environmental Information, US EPA, Washington, DC.

DATA MANAGEMENT

Introduction

High-quality data management is as important to a project as is high quality sampling and analysis. Improperly handled data can result in misreporting or omission of data, ultimately leading to misinformed water quality management decisions. While this concept is generally appreciated by those involved in watershed assessment projects, scant resources have been allocated to data management. "Data Management" includes time spent collecting and recording sample project and sample event meta-data, creating new stations in the database, entering field and laboratory data, verifying data, performing QA/QC checks on data, and transferring data between various databases. Spending the time and resources necessary to assure high-quality data management will maintain the integrity and total quality management of any water quality project.

Following Standard Operating Procedures for collecting and analyzing water quality samples assures high quality analytical results. In order to transfer these high-quality analytical results into high-quality information, methods for managing the data and information products should also be standardized. Data management, for the purposes of this discussion, begins when the analytical result is transferred to the recording medium (paper or electronic) and ends when the validated data are verified as complete and accurate in their ultimate destination. That destination is a data repository that is easily accessible to persons interested in the data. Presently, validated data are released from LIMS (Laboratory Information Management System) to LASAR (Laboratory Analytical Storage and Retrieval) and then uploaded to STORET (EPA's STOrage and RETrieval).

LASAR data are available at http://deq12.deq.state.or.us/lasar2/

STORET data are available at http://www.epa.gov/storet/dbtop.html.

The Laboratory's Technical Services section is largely responsible for data management. Sample tracking, LIMS/LASAR development and management, and related documentation and support are among the services provided by this section. Contact Technical Services for the most current information regarding data management.

A graphical representation of the data management process for WA section data is given in **Figure 3** and **Figure 4**

Figure 3 (Sample Collection to Sampling Event Data Entry Complete)

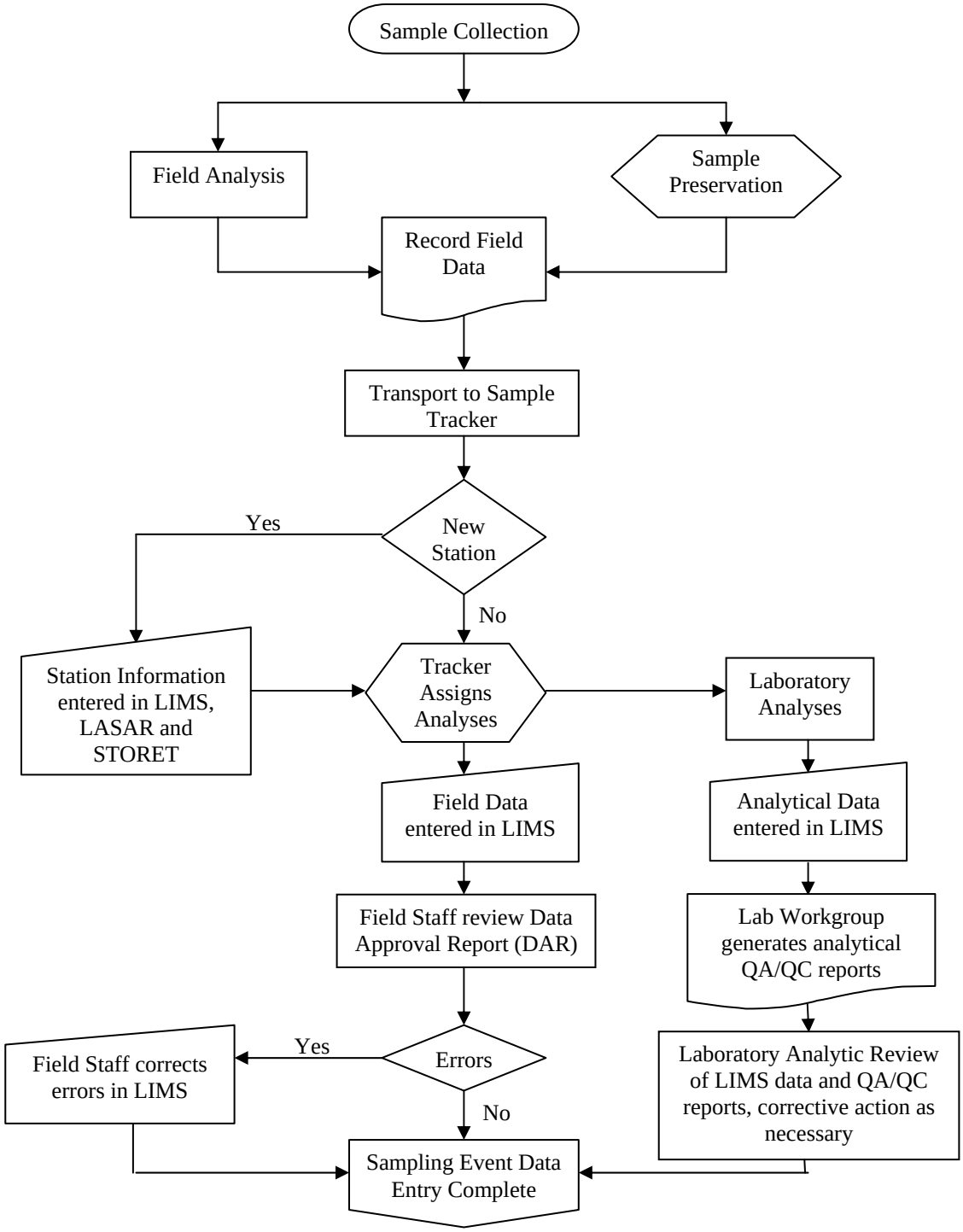
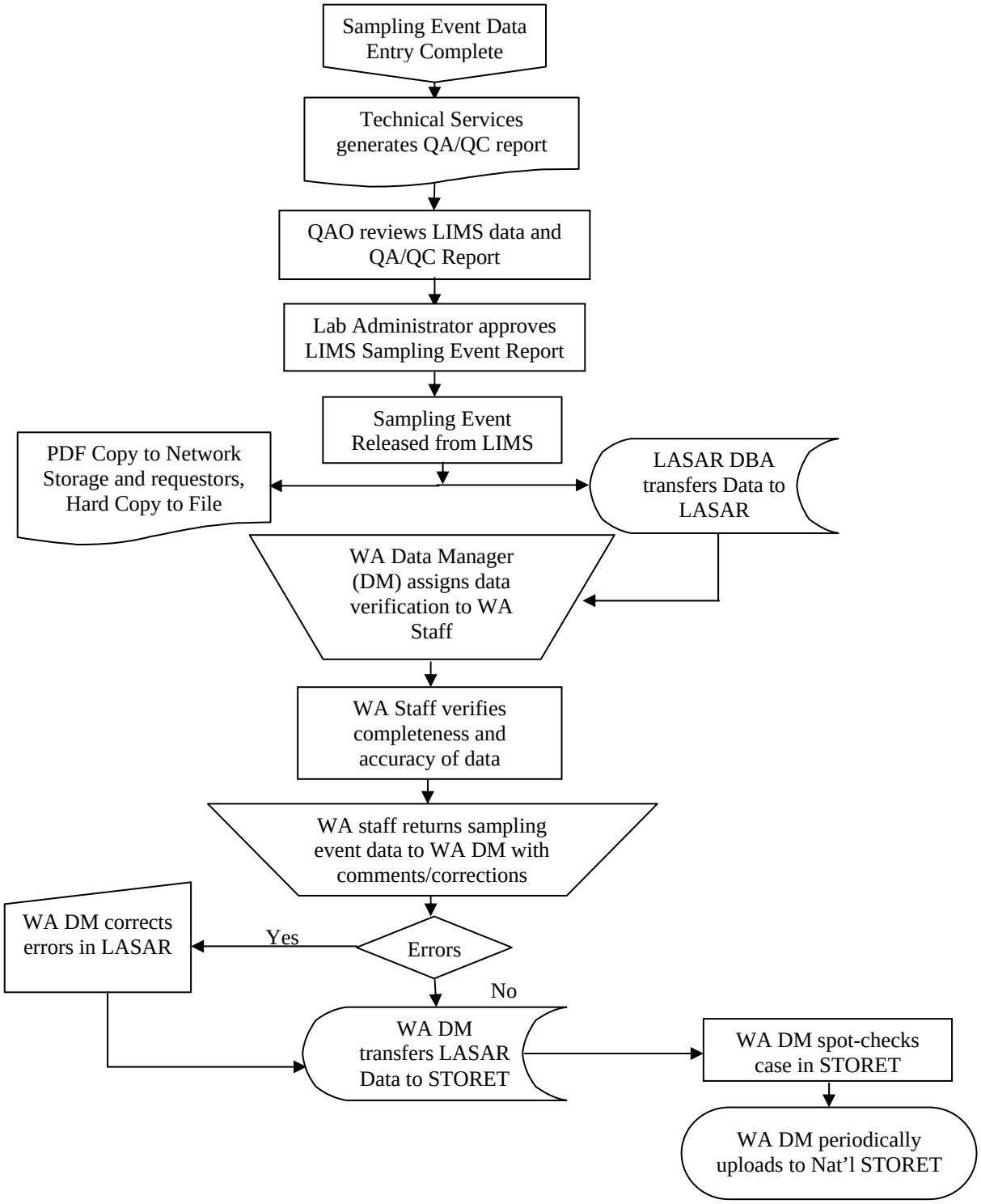


Figure 4 Data Management Flowchart
(Sampling Event Data Entry Complete to Storage in STORET)


Sampling Event Data Entry Complete
Technical Services generates QA/QC report
QAO reviews LIMS data and QA/QC Report
Lab Administrator approves LIMS Sampling Event Report
Sampling Event Released from LIMS
PDF Copy to Network Storage and requestors, Hard Copy to File
LASAR DBA transfers Data to LASAR
WA Data Manager (DM) assigns data verification to WA Staff
WA Staff verifies completeness and accuracy of data
WA staff returns sampling event data to WA DM with comments/corrections
WA DM corrects errors in LASAR
Yes
Errors
No
WA DM transfers LASAR Data to STORET
WA DM spot-checks case in STORET
WA DM periodically uploads to Nat'l STORET

LIMS Sample Event Creation and Data Verification

This discussion assumes that an approved QAPP and/or SAP exists for the monitoring project. If new stations and/or test methods will be established, enter as much information regarding the stations or methods as possible into LIMS prior to samples arriving at the lab.

After samples are taken and/or field data are recorded, these are transported to the sample tracker. The sample tracker assigns a Sampling Event (formerly known as LIMS Case) number to the collected samples and/or data and assigns analyses to the chemistry sections. If the sample is from a new station not yet in the database, the sample tracker informs the sample collector or other appropriate person, who creates the new station in LIMS. The sample cannot be released from LIMS until they can be assigned to a sample station.

After field data are entered into LIMS, the sample tracker scans the field sheets into LIMS. Scanning the field sheets enables tighter control of data sheets after data is entered into LIMS. The sample collector (or other responsible party) is responsible for comparing the LIMS Data Approval Report (DAR) to the scanned field data sheet to ensure that the entered field data are complete and accurate. This data review extends to ensuring that sample location, date, and time were recorded correctly. The sample collector is responsible for either making corrections or ensuring that corrections are made. The sample collector approves the DAR in LIMS, stating that it is complete and accurate.

Meanwhile, chemists perform assigned analyses and enter the data into LIMS, after which a Laboratory DAR is generated. The chemistry sections also perform QA/QC analyses applicable to the individual method. After the appropriate chemistry sections have reviewed their data and QA/QC data and performed corrective activities as necessary, data entry for the sample event is considered complete.

When sample event data entry is complete, the QAO reviews LIMS data and QA/QC Reports for the sample event, and passes the Sampling Event to the Lab Administrator who approves the LIMS Sampling Event Report. If approved by the Lab Administrator, the Sampling Event report is released to the public. Agency contacts will receive an e-mail notice with a hyperlink to a PDF copy of the analytical report. Recipients must specifically request to receive reports in a different format. The sample event data are uploaded to LASAR.

The WA Data Manager (DM) assigns data verification for the sample event to the sample collector or other appropriate party. This data review by the monitoring staff member will verify data completeness and accuracy for the sampling event. Monitoring staff should complete data verification as quickly as possible to minimize time that erroneous data are available to the public. Since the sample collector is most familiar with the source of the sample and the conditions under which it was taken, the sample collector will be more likely to find data reported with incorrect units, wrong order of magnitude, or otherwise not reasonably close to the expected value. It is the responsibility of the sample collector to resolve the error, if it is an error, and report all findings to the WA DM. The WA DM makes corrections to the data, as necessary.

The WA DM transfers data from LASAR to the local copy of STORET and spot-checks the transfer in STORET. The WA DM periodically uploads the local copy of STORET to the National STORET Warehouse.

Continuous Monitoring Variation

Continuous monitoring equipment is used to gain a more thorough understanding of variability of certain water quality parameters than can be obtained through grab sampling. Using various

types of equipment, parameters monitored in this manner include water and air temperature, water depth, pH, dissolved oxygen, conductivity, salinity, turbidity, relative humidity, and solar radiation. While operation of these various types of equipment differs, data management and QA/QC concerns are similar.

Prior to deployment, the continuous monitoring equipment undergoes pre-deployment checks in the laboratory to assure that the parameters of interest can be accurately measured. Upon deployment in the field, the equipment is allowed to equilibrate to ambient conditions. Then the parameter monitored is independently measured (audited) to assure that ambient conditions are accurately measured by the continuous monitoring equipment. Audits are conducted at specified times during the length of the deployment and just prior to retrieval from the monitoring site. Although auditing can be time-intensive, higher frequency auditing provides higher data quality assurance. The more important the data collected are, the higher frequency field staff may consider performing audits. In addition to field audits, duplicate monitoring equipment may be deployed for QA purposes or at sites where there is concern that equipment may be lost or stolen. Duplicate equipment may also be deployed at sites deemed of critical importance where a backup data source is desired in case of equipment failure.

After continuous monitoring equipment is retrieved from the field, a reasonable number of monitoring stations/equipment is submitted together as a "Sampling Event". A Required Report Form serves as a cover sheet for the entire report. For the requirements to properly define the data contained in the continuous monitoring sample event, see the section on meta-data. The sample tracker assigns a sample event number. If one of the monitoring stations is new and not yet in the database, the station must be created in LIMs prior to release of the data.

Data are downloaded from the equipment and checked against audit values for QA/QC. Each data point receives a grade based on comparison to the audit value and pre-deployment/post-retrieval accuracy checks. Data points failing audit and prior data back to the previous successful audit will be omitted, leaving a sample time and a grade "C" accompanying the omission. For each monitoring station and each piece of equipment, a graph of the data with superimposed audit values and error bars is printed. Also printed is a QA/QC report summarizing results for that piece of equipment. This information will allow the operator to determine whether anomalies exist in the data, including equipment malfunctions and emergence of the equipment from the water due to low flow. The operator will modify the data or the grade of the data based on this review of data. Sample time recorded from the continuous monitoring equipment is standardized to Pacific Standard Time, but can be retrieved as either Standard or Daylight Savings time to synchronize with grab sample data.

After the data and grades are uploaded to LIMS, they are spot-checked to assure that the data transfer was error-free. The QA/QC report is reviewed by the WA Section Manager or designee, the QAO, and the Laboratory Administrator prior to release of the data to LASAR. These data are spot-checked in LASAR. The WA DM transfers data from LASAR to the local copy of STORET and spot-checks the transfer in STORET. The WA DM periodically uploads the local copy of STORET to the National STORET Warehouse.

For further information about continuous monitoring data management, please see the Continuous Data Quality Control and Quality Assurance section of Chapter 5 - Continuous Monitoring Methods.

Sample Collection Activity Meta-Data

With the exception of ambient surface water quality monitoring network sampling, WA sampling projects tend to be non-routine in terms of why and where the samples were

taken. It is important to obtain sufficient meta-data (i.e., information about the data that is collected) to allow users to make full and effective use of the data, and understand the quality of the data over time. WA staff generally submits data sheets that are unique to the project. It would be preferred to standardize data sheets, as much as possible, so that the sample tracker can easily find these data elements and more efficiently do his/her job. The following data elements must be submitted along with field analytical results and sample container numbers.

1) **Sample Subproject Code**, LIMS/LASAR classification of the monitoring activity, as stored in the Sample Subproject Table. The Sample Subproject table also stores the Subproject's SAP. Each Subproject shall have an SAP.
2) **Station ID Code**. This is the LASAR Station number and it relates to a STORET Number, if applicable.
3) **Station Name**
4) **Location**, if the station is new. Latitude and longitude, either in degrees, minutes, seconds or in decimal degrees. Include the method used to obtain this information, including datum and map scale if applicable.
5) **Elevation**, in feet. If the station is new, indicate method used to obtain this information.
6) **River mile**, where applicable.
7) **Sample depth,** where applicable. This is reported for groundwater monitoring, typically, as two pieces of data: depth to bottom and depth to water. For surface water, this is reported when sampling at non-standard depths, such as during horizontal profile sampling, or when sampling at Secchi depth in lakes or estuaries.
8) **Date of sample collection**. Use MM/DD/YYYY format (*Example:* 05/31/1999).
9) **Time of collection.** Use the 24 hour clock and HH: MM format (Example: 14:35 *to designate 2:35 p.m.*). Report all sample times as either Pacific Standard or Pacific Daylight Savings Time.
10) **Method(s) used in sample collection,** if non-standard. The method should be specified in the sample project's QAPP or SAP.
11) **Sampling equipment type and tag number**.
12) **Sample Matrix**. This describes the physical state of the sample, i.e., "surface water", or "sediment".
13) **Sample Classification,** i.e., trawl, time composite, area composite, volume composite, continuous, or grab.
14) **QA/QC Classification,** i.e., equipment blank, QA duplicate, etc.
15) **Sample Comments**. Any comments, if appropriate.

Field Analysis and Data Collection

Most WA section field data collection relies on either direct observation (or estimation), instrumental analysis, or chemical analysis of the environmental variable. In order to assure the highest quality data, staff should carefully consider analytical uncertainty and significant digits, rounding error, and units of measurement. More on this subject can be found in Bevington and Robinson (1992).

Analytical Uncertainty and Significant Digits

Any measurement is prone to error; thus, it is impossible to be certain that our result is a true measurement of the environmental variable under consideration.

Blunders

One class of errors originates from blunders in measurement or computation. Blunders are usually obviously incorrect or not reasonably close to expected values, and can be eliminated by careful re-measurement or recalculation.

Accuracy and Systematic Errors

Accuracy is a measure of how close the observed value is to the true value. Accuracy is dependent on how well we can control systematic errors, such as faulty equipment calibration or observer bias, which make our results different from the true value with reproducible discrepancies. Systematic errors may be reduced by maintaining strong QA/QC and training programs and regular equipment maintenance.

Precision and Random Errors

Precision is a measure of how well the result has been determined, regardless of its accuracy. It is also a measure of the reproducibility of the result. Precision is dependent on how well we can compensate for random errors, such as instrumental error or subsample variation, which cause results to vary between observations. Random errors may be reduced by improved methods, refined technique, improved instrumentation, or by repeated measurements.

Accounting for Uncertainty

Perhaps the best way to account for analytical uncertainty is to quantify and document it as part of the analytical result. For example, by performing multiple measurements on a series of standards, a chemist can derive a standard curve relating observed measurement to analyte concentration, within a quantified estimate of error. This can be expressed as absolute precision (i.e., 1.979 mg/L ± 0.012 mg/L) or as relative precision (i.e., 1.979 mg/L ± 0.6%). The reality of a fast-paced working environment precludes such circumstantial determinations of uncertainty. WA section uses methods with documented acceptable error levels, analytical equipment that can read a standard solution within an acceptable error level, and other QA/QC checks (i.e., blank and duplicate analyses) to minimize uncertainty. However, the remaining uncertainty is not documented with the analytical result. Another way to account for analytical uncertainty is to be conservative in the way the result is reported. When using electronic analytical equipment, the analyst's first instinct is to report the value (i.e., 4.74 NTU) displayed by the instrument without first considering analytical uncertainty. Following this instinct places more confidence in the least significant digit than is prudent. **Table 1** describes the accuracy of typical field analyses and requirements for reporting results. This table should be used as a guideline for determining how to report results for other analyses.

Table 1 Requirements for Reporting Field Analysis Results

Analysis	Method or Instrument	Scale	Rel. Precision	Abs. Precision	Recommendation
DO concentration	Winkler Titration			±0.1 mg/L	Report to tenths
DO Saturation	Calculation			0.7-1.4%	Report whole units

Analysis	Method or Instrument	Scale	Rel. Precision	Abs. Precision	Recommendation
pH	Digital meter, combination electrode with ATC probe			±0.1 SU	Report to tenths
Alkalinity	Potentiometric (pH) titration			±1.0 mg/L	Report whole units
Temperature	YSI Model 30			±0.1°C	Report to tenths
Conductivity	YSI Model 30	0-499.9 µmhos/cm	±2% Full Scale	±10 µmhos/cm max	Report 2 sig. digits
	YSI Model 30	0-4999 µmhos/cm	±2% Full Scale	±100 µmhos/cm max	Report 2 sig. digits
	YSI Model 30	0-49.9 mmhos/cm	±2% Full Scale	±1 mmhos/cm max	Report 2 sig. digits
	YSI Model 30	0-200 mmhos/cm	±2% Full Scale	±4 mmhos/cm max	Report 2 sig. digits
Salinity	YSI Model 30	0-80 ppth	±2% FS or 0.1 ppth	±1.6 ppth max	Report up to 2 sig. digits
Turbidity	Hach 2100P Turbidimeter	0-10 NTU *(<1.0 NTU)*	±2% Full Scale	±0.2 NTU	Report 1 sig. digit *(Report"<1 NTU")*
	Hach 2100P Turbidimeter	0-100 NTU	±2% Full Scale	±2.0 NTU	Report 2 sig. digits
	Hach 2100P Turbidimeter	0-1000 NTU	±2% Full Scale	±20 NTU	Report 2 sig. digits

Rounding Error

Misunderstanding rounding rules leads to systematic errors in reporting values either too high or too low. To round off a number, note the number to the right of the desired least significant figure. Compare to the number 5, or 50, or 500, etc., depending on the number of digits to the right of the desired least significant figure.

1) If the number is greater, increase the least significant figure by 1. Example: To report two significant digits, 175.1 becomes 180.
2) If the number is less, leave the least significant figure as is. Example: To report two significant digits, 174.9 becomes 170.
3) If the number is equivalent, increase the least significant figure by 1 if it is odd or leave it as is if it is even. Example: To report two significant digits, 175.0 becomes 180 and 185.0 becomes 180.

Using the third rule as the convention reduces systematically high or systematically low values that would otherwise influence the average of a group of such numbers. In short, **round to even.**

Units of Measurement

The importance of reporting correct units of measurement cannot be overstated. Inattention to such detail as conversion of units between metric and English systems of measurement led to the crash of the Mars Climate Orbiter into the surface of Mars. While our mission is not as critical, entry of salinity as "ppt" has led to reporting salinity as parts per trillion, rather than parts per thousand (ppth), nine orders of magnitude difference. Ensure that units of measurement are clearly marked on the field analysis sheet and that they are properly entered into the database. When verifying the accuracy and completeness of collected data, ensure that the units and/or order of magnitude of the result are correct.

In summary, WA staff is responsible for providing required meta-data elements, as well as carefully considered field analytical results. This provides a high-quality foundation upon which subsequent analyses are based.

References

Bevington, Philip R. and D. Keith Robinson, 1992. Data Reduction and Error Analysis for the Physical Sciences, Second Edition. McGraw-Hill, Inc., San Francisco, California.

DATA ANALYSIS

Department staff uses Water Monitoring and Assessment data for a variety of purposes. Some of the routine uses are identified below.

All data is evaluated every two years to determine the extent to which surface and ground water bodies meet water quality standards and types of impairment. This evaluation is a major part of the preparation of the Water Quality-Limited Streams 303(d) list, as well as the Water Quality Status Assessment 305(b) Report.

Much of the data collected is used by regional watershed specialists and TMDL modelers to develop and assign load and waste load allocations. The collected data serves as ground-truthing information for GIS and numeric water quality models. Ground-truthing is an analysis of the validity of GIS data and model information. As the agency moves to a water quality based permitting approach, NPDES permit writers will evaluate water quality data for receiving streams prior to issuing new or renewed permits.

Ambient river monitoring data is used to develop an Oregon Water Quality Index (OWQI) score for every sample. The water quality index data is then used to rank sites, identify spatial and temporal variability, and communicate water quality conditions to the public. Ten-year trending analysis based upon the OWQI is conducted for all ambient network sites. Trend data is used to measure progress and is a primary environmental indicator for the Performance Partnership Agreement with EPA and the Oregon Progress Board Benchmarks Program.

Probabilistic sampling plans, such as the Oregon Plan for Salmon and Watersheds and Regional and Coastal Environmental Monitoring and Assessment Programs (REMAP and CEMAP), collect data from randomly selected locations in water bodies in selected areas. Indicators are selected and measured to determine types of impairment, and cumulative distribution functions are developed for each indicator for the study. This data is used primarily to:

- Determine the status of conditions in water bodies critical to the survival and recovery of threatened or endangered fish species across the state.
- Identify trends in water body conditions within areas with listed fish species.
- Identify chemical and physical parameters impairing water body conditions.
- Help determine the effectiveness of restoration projects and changes in management practices in improving conditions for listed fish species.

Data collected for Best Management Practices (BMP) monitoring, whether for surface or groundwater, are evaluated to determine long-term trends and the effectiveness of the BMP plan.

Data are also collected to monitor water quality permit holders for compliance with water quality standards. In this case, DEQ data are either directly compared to standards, or are collected simultaneously with the permittee's contracted monitoring organization for comparison to assure their data are of sufficient quality.

It is imperative that data used for analysis are of known quality. The data should have documented Precision, Accuracy, Representativeness, Comparability, and Completeness (PARCC). More information on this topic can be found in the QA/QC section of this manual. The data used for analysis should come from a sample design that allows for the desired analytical use. The analyst should carefully choose numerical methods of analysis. See the references listed below for guidance in environmental statistics. In this manner, the results of the analysis and policies that may be evaluated or changed as a result, are based on defensible, sound science.

References

Gilbert, R. O., 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold Co., New York.

Helsel, D. R., Hirsch, R. M., 1991. Statistical Methods in Water Resources. Appearing as Chapter A3 in Techniques of Water-Resources Investigations of the United States Geological Survey Book 4, Hydrologic Analysis and Interpretation. US Geological Survey, Reston, Virginia.

Sanders, T. G., R. C. Ward, J. C. Loftis, T. D. Steele, D. D. Adrian, V. Yevjevich, 1994. Design of Networks for Monitoring Water Quality. Water Resources Publications, Highlands Ranch, Colorado.

SAFETY

One of the primary objectives of the Water Monitoring and Assessment Sections is to provide high quality data so that the agency can make informed decisions. Unless the health and safety of our staff is monitored and protected, the quality of our data will suffer. Healthy, alert monitoring staff is better able to produce high quality work than is ill, injured, or groggy staff.

The DEQ Central Safety Committee and the DEQ Laboratory Safety Committee strive to meet or exceed Oregon Occupational Safety and Health Administration (OR-OSHA) regulations to protect our health while on the job. These programs are documented in the DEQ General Health and Safety Policy, DEQ Health and Safety Program, the DEQ Laboratory Safety Manual (Chemical Hygiene Plan), and the DEQ Laboratory Safety video. Hazards associated with specific tasks and measures to mitigate those hazards are documented in Job Safety Assessments (JSA), which are on file with the agency's Safety Coordinator. All staff must read the above documentation and be trained. Such training must be documented. The purpose of this section is to accentuate safety topics of particular interest to WA section staff.

General Safety

There are many hazards inherent to our jobs, whether we're working in the laboratory, collecting or analyzing environmental samples in the field, or transporting ourselves during monitoring via motor vehicle, boat, hiking boot, or wader. In order to ensure that these hazards are recognized and understood, all new employees are required to understand the contents of the documents referenced above. In the case of the DEQ General Health and Safety Policy and Job Safety Assessments, the employee's signature documents that these policies are understood. All employees should be familiar with the location of potential hazards and safety equipment in their immediate workspace, throughout the lab, in vehicles and boats, and in the field.

Documentation: The DEQ General Health and Safety Policy is included in the packet of materials given to new employees, and is also available in the laboratory front office area. Copies of the DEQ Health and Safety Program and the DEQ Laboratory Safety Manual (Chemical Hygiene Plan) are located in the laboratory front office area, and are also available from the Laboratory Safety Committee representatives. The DEQ Laboratory Safety Video is available from the Laboratory Chemical Hygiene Officer (and QAO). Job Safety Assessments are available from your section's Safety Committee representative.

All employees should be familiar with evacuation routes and designated assembly areas for their work location. For the laboratory, the designated assembly area is in the parking are on the Southwest side of the outbuilding. In case of evacuation, meet at the designated assembly area, check in with your Emergency Coordinator (section safety committee representative, section manager for back up), and remain with your group until further notification.

Laboratory Safety / Chemical Hygiene

When working in the lab or performing chemical analyses in the field, it is imperative that you protect your eyes. Safety glasses are available at the lab. Prescription safety glasses will be provided if necessary. Perhaps the best eye protection is given by vented goggles.

Hands and fingers are susceptible to chemical exposure due to their proximity to samples and reagents. It is important to match the protective glove to the chemicals used. For most work performed by our sections, PVC gloves are sufficient. Inspect and carefully handle glass bottles, beakers, and other glassware to prevent cuts from chips or cracks.

Other areas of your body are also susceptible to chemical burns. Protect exposed skin with clothes that you don't mind damage to, or further protect your skin and clothes with a lab-coat or coveralls. Personal protective equipment (PPE) will be provided by the lab.

Label all chemical containers so that personnel are cognizant of the container's contents. Information on labels should include chemical name, concentration if applicable, date filled, expiration date, and initials of the person filling the container.

Chemical waste produced from our sections' water quality analyses must be contained (if produced in the field) and disposed of in any deep sink in the laboratory. Spent concentrated acids and bases should be neutralized or diluted and flushed down the deep sink with excess water: ***turn on a faucet in a laboratory sink and then slowly pour the chemical into the stream of water to be flushed down the drain.*** Before discharge into the sewer this material passes through a pH-monitored neutralization tank, maintained by the Department of Administrative Services, this ensures neutralization. Other wastes, such as ethanol or formalin, require special handling for which special procedures have been developed. Contact your Safety Committee representative for more information. Under no circumstances should chemical waste be disposed of in the field. Ensure you have adequate or excess waste container capacity before leaving for field monitoring expeditions.

Documentation: For specific information regarding chemical reagents, refer to the chemical's Material Safety Data Sheet (MSDS). MSDSs are maintained in notebooks located in the laboratory front office area.

Field Safety

All field staffs are required to complete First Aid and CPR training every two years. This ensures that staff can care for each other in case of a medical emergency in the field. Additionally, field staff responsible for spending long periods of time in remote areas may be trained (or accompanied by a staff member that is trained) in wilderness first aid. This training will also be updated every two years. These courses are typically offered by DEQ every June.

A significant portion of field monitoring activities is driving to monitoring locations. Fatigue from long hours behind the wheel of a vehicle or boat puts monitoring staff at considerable risk. Travel with a partner, whenever possible, to share driving responsibilities. Employees are to avoid working long hours and driving while tired. Defensive driving courses are offered by DEQ and are required of new employees responsible for driving state vehicles. The course must be repeated every five years.

Boater Education is required before an employee can drive state boats. The Mandatory Boater Education course is available from a variety of outlets. After completing the course, staff must apply for a Boater Education card. This card must be carried at all times while operating a boat. The card is good for life and the course has no continuing education requirement.

Work on bridges and on roadway shoulders exposes staff to hazards from passing vehicles. Increasing your visibility to motorists, minimizing your exposure time, and keeping one eye on approaching traffic are effective ways of minimizing risk. When working on the road, staffs are required by OR-OSHA (OR-OSHA, 2001, OAR 437-003-0128) to wear an article of high-visibility clothing (such as a vest); viewable from 360° (open-sided vests are obsolete). If lighting is poor or visibility is low, use a vest with reflective tape. Where possible, position your vehicle between approaching traffic and the work site. Use flashing/rotating lights on your vehicle and station a "Workers Ahead" sign between approaching traffic and the work site. Stage safety cones in advance of your work zone, whether it is on the bridge or on the roadway

shoulder. Taper the cones from the edge of the shoulder furthest from the roadway, or from the bridge railing, to the fog line on the roadway. The distance between the cones in the taper should equal in feet the designated speed, e.g., 55 mph = 55 feet (ODOT, 1998). The intent of safety cone staging is to alert the motorist's attention to work zone activity and to direct the motorist to drive away from the work zone. Plan your work to spend the least amount of time possible on the bridge or on the shoulder. When on the bridge, employ one monitoring staff as a "spotter". The spotter keeps an eye on traffic while the other staff draws the sample. If visibility is limited or traffic is especially heavy or fast, consider staging the spotter at the end of the bridge. Use of a whistle or two-way radio is an effective means of communicating the approach of potentially hazardous motorists. While drawing the sample from the bridge, take great care. Slipping and falling off the bridge could be fatal.

Sampling from a boat poses its own challenges. One person onboard should be responsible for monitoring boat traffic and weather/water conditions both visually and on the radio. OR-OSHA requires (OR-OSHA, 2001, OAR 437-002-0139) that personal floatation devices (PFDs) are worn at all times. When maneuvering the boat trailer at the boat ramp, or in other cramped maneuvering spaces, clear communications must be maintained between the driver and the trailer spotter on the ground. Towing a boat or other pieces of monitoring equipment requires that the driver be familiar with associated hazards including longer distances to stop and safety equipment such as safety chains and proper trailer lighting.

When sampling from the bank, from a boat dock, or instream, where the danger of drowning exists and water is greater than five feet, OR-OSHA requires (OR-OSHA, 2001, OAR 437-002-1139) that personal floatation devices be worn.

Hiking/backpacking, wading, and climbing to or along monitoring sites exposes staff to injuries from falls, sprains/strains, stick-pokes, bites, stings, etc. Due care should be taken while working far afield due to the distance from medical facilities. A two-day wilderness first aid course is available to staff who work in those conditions.

Backpack electro-shockers are used to stun and collect fish in wadeable streams. There is a risk of shock to personnel instream when electro-shocking is underway. All personnel instream should wear waders that are electrically insulating. Staff performing electro-shocking should keep their eyes and ears open for the possibility of another staff slipping and falling into the water and receiving a shock.

Staff involved in sampling at hazardous waste sites will receive training on the selection and use of respirators and other Personal Protective Equipment (PPE). They will also receive training on Hazard Communications. They will also be properly fitted with respirators and receive medical monitoring to ensure that any exposure to hazardous chemicals is detected and cared for. These staff will also be advised on safety plans that are specific to the sites they visit.

Field staff must carry a cell phone or satellite phone into the field. Staff must call into the lab every day, preferably near the end of the day, to check in. Staff should leave a message with their manager (if available), or front office staff, or on the lab's general message voice mail. Staff should advise of their location, health status, projected activities for the next day, and any other pertinent information. Using these measures, communications between field staff and the lab will be more feasible in the event of emergency. If field staffs fail to check in and it is feared that they may have been involved in an accident, it will enable lab staff to more precisely locate field staff for emergency personnel.

Accidents

Accidental spills of hazardous chemicals can pose a significant risk to staff. Spills of small quantities (less than 15 L) that are of minimal health risk can be contained, neutralized, or collected using absorbent materials by our staff. Consult the Laboratory Emergency Operations Plan (DEQ, 2002) and applicable MSDS for appropriate clean-up methods and PPE. For large spills, evacuate the area and call 911.

For any accident involving personal injury, seek first aid or medical attention immediately and inform your manager regarding severity. DEQ requires that an Accident/Incident Report, "Form DEQ 34", available from the Front Office, be filed with 24-hours following an accident or incident where the potential for injury could have occurred. When medical treatment is required for a work-related injury or illness, fill out a State of Oregon Worker's and Employer's Report of Occupational Injury or Disease, SAIF Corporation, Form 801, available from the Front Office. The supervisor must complete this report and mail or fax it to SAIF and Human Resources. This report must be provided to SAIF within 36 hours of the incident.

Conclusion

Safety regulation, training, and documentation will be effective in minimizing workplace accidents and injuries only when combined with working carefully and paying attention to the task at hand. If working conditions are dangerous, consider postponing your work until appropriate safeguards are in place. If you any questions or concerns regarding safety, contact your section Safety Representative and/or manager.

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SAMPLING PREPARATION

Background

This section provides general guidance on how to prepare for field sampling expeditions based on completed Quality Assurance Project Plans (QAPPs) (please see Chapter 2, Project Planning Section). The key to a successful sampling expedition is to start early and to be prepared for delays due to missing or broken equipment. More complex sample expeditions require more preparation time.

Preparation includes more than simply gathering needed supplies. Preparation includes understanding the purpose of the project and being familiar with the procedures you will be performing. Read the project plan for descriptions of who will be using the information you collect and how. Understanding the end use of your data will help you make good decisions in the field when unforeseen circumstances force you to make changes in the project plan. Whenever practical, bring extras, backups and replacements of required supplies and equipment. Sampling expeditions are expensive and missing data due to broken equipment or forgotten supplies can undermine the value of the expedition.

Project Plans

The first step in preparing for a sampling expedition is to be familiar with the project plans: QAPPs and Sampling and Analysis Plans. The project plans will define what methods are being used, when the samples will be collected, where to collect samples and how many measurements will be made. Make sure you are familiar with the methods you will be using—refer to the appropriate sections of the MOMs manual for details on each method. If a method is unfamiliar to you, practice the procedures before you collect "real" data.

Checklists

Checklists are strongly recommended for helping in sample preparation. Checklists may already be available for some standard expeditions, like the ambient river monitoring network, and can be adapted to fit your sampling needs. Prepare and label a staging area in the outbuilding or in your work area where you can store your supplies. Be sure your pile of sampling supplies does not block safe passage through exits or loading doors and that it does not get piled so high as to become a threat for other users in the area. Clearly label your stack of supplies with your initials, the date of your planned departure and where you are going.

Gathering Equipment

Most equipment should be readily available for use, but some equipment will need to be checked out, borrowed or bought. NEVER take any piece of equipment from a labeled stack of supplies or if you are unsure of whose equipment it is—ask before taking. Many shared pieces of equipment need to be checked out in advance including vehicles, boats, multi-parameter data loggers, GPS units, cameras and cell phones. The earlier you check equipment out, the more likely the equipment will be available when you need it.

All equipment needs to be inspected to assure that it is in proper working order prior to departure. Calibrate or check all field meters as described in the appropriate MOMs Section. Bring a back-up meter whenever possible. You should be familiar with the operation and maintenance of any

piece of equipment before you take it into the field. Ensure that reagents, buffers, and standards are not beyond their expiration date (as indicated on the container, see appropriate MOMs sections for individual analyses) or otherwise appear contaminated. Spent concentrated acids and bases should be neutralized or diluted and flushed down the deep sink with excess water: ***turn on a faucet in a laboratory sink and then slowly pour the chemical into the stream of water to be flushed down the drain.*** You can read the appropriate MOMs sections, review equipment manuals and do practice measurements to make sure you and the equipment are working correctly. Take any field replaceable supplies such as batteries, probe filling solutions, hosing, etc. Check to make sure the vehicle is in good working condition and has all necessary safety and field sampling equipment.

Field Data Sheets

Field data sheets are requests for analysis forms that identify the test or parameter screen needed on samples. Any samples turned into the lab for analysis must be accompanied by one of these forms. The analysis request forms must also include field sampler's initials, project fund code, sample location, LASAR # for sample location, time of collection, sample bottle numbers, on-site measurements and observations, weather conditions, and other conditions that may affect the sample.

Travel Plans

Make hotel reservations in advance and get good directions or a map to the hotel. If you will be shipping samples back to the lab, make sure you are familiar with the shipping times and locations. Have a back-up plan if you are unable to make your intended shipping times. Before you leave the office, sign out on the office Whiteboard and give any contact information. While in the field, call your supervisor or administrative personnel once per day during business hours to assure them that you and your partner are accounted for.

LOGISTICS

General Considerations

Logistics involves all phases of sample handling and shipment. After samples have been collected, they must be properly stored until ready to ship or deliver to the laboratory for analysis. They must be prepared to withstand the handling involved in transit from the field to the laboratory. Some samples are collected and transported to the Laboratory by the field personnel, but most samples are shipped to the Laboratory. Analytical holding time requirements often require overnight delivery, which can be difficult from certain parts of the state. Advance planning is necessary to determine shipping points and carriers.

Most of the samples collected by the Water Monitoring and Assessment Sections are shipped to the DEQ Laboratory for analysis. However, other laboratories may also be used. Be sure to have all of the information (address, carrier, notification requirements, etc.) necessary for shipping to the proper laboratory.

Water samples are stored and shipped in coolers (ice chests). A supply of coolers of various sizes is kept in the wash-down area in the lab. Select the proper size and number of coolers based on the volume of samples to be collected. Be sure to allow space for enough ice to maintain the samples at the proper temperature (4° C.) for at least 30 hours.

Weight Limit

The DEQ Laboratory restricts the weight of any Water Monitoring and Assessment shipping container to 50 pounds or less.

The number of coolers needed for a particular sampling event should be determined in advance, so that the weight limit is not exceeded. For example, a cooler containing four sets of ambient surface water samples, plus ice will weigh just less than 50 pounds.

Special Samples

Samples for chlorophyll analysis are not shipped to the Laboratory. They are transported back by the field personnel. Chlorophyll samples must be stored frozen in Styrofoam packers on dry ice. Sufficient dry ice should be included for the entire expedition. Dry ice should be ordered from the purchasing officer at the lab. Try and give notice to order the dry ice a week before it will be needed. A good rule of thumb is to pack 10 pounds of dry ice per day during hot weather. Dry ice may be hard to replenish in the field.

Some other samples (fish tissue, sediment, etc.) may also need to be frozen in the field and kept on dry ice for delivery to the Laboratory.

Other samples may require special handling. Handling of non-routine samples should be covered in a Quality Assurance Project Plan.

Materials

The materials necessary for shipping samples may vary depending on the types of samples to be collected and the carrier(s) used. A checklist should be tailored to the sampling event to assure that all of the necessary materials are included. Some of the items common to most sampling events include:

- Coolers of the proper size.
- Shipping manifests for all carriers that will be used. Pre-printed forms are available from the DEQ Laboratory office.
- Reinforced tape for taping shut the cooler lid during transit.
- Ziploc bags for field sheets that are included in the cooler.
- Blue ice or water ice for cooling samples and maintaining sample temperature. (Dry ice for those samples requiring freezing)

Packaging

Samples in plastic containers can be shipped without further preparation. Samples in glass containers should be protected from breakage. This may include wrapping in paper, wrapping in bubble wrap, etc. "Fragile" stickers are available from most carriers at the point of shipment.

Packaging of coolers for shipment may vary according to the carrier used. The following points apply to all carriers:

- Coolers should be in good condition. Check hinges and handles prior to use. Coolers should be clean and dry.
- The cooler should have the DEQ Laboratory address printed on the outside in permanent ink. If the shipping label comes off in transit, this gives the carrier the necessary information to contact the Laboratory.
- The drain plug should be taped shut with reinforced shipping tape.
- Field sheets should be placed in Ziploc bags and taped to the inside of the cooler lid.
- The lid of the cooler should always be taped shut for shipment. Some carriers (especially Horizon) may inspect the contents prior to shipment. The lid may be taped shut following their inspection.

Shipping

Samples can be shipped to the DEQ Laboratory (or other destinations) via several carriers. These include:

- Horizon Airlines
- Greyhound Bus
- United Parcel Service (UPS)

The use of any other carrier requires pre-approval from Administration.

Special Considerations

The DEQ Laboratory Water Monitoring and Assessment Sections have received special approval from Horizon Airlines to ship samples with water ice. Horizon normally requires non-liquid (blue) ice for shipment. Special heavy-duty plastic bags are available in the dishwasher/autoclave room. The water ice must be contained within one of these heavy bags. The bag must be secured using plastic ties.

Always check the office hours for the carriers prior to the sampling event. For the routine ambient surface water runs, this information is included in the run notebooks. However, remember that the carrier may change the office hours at any time. A telephone call prior to leaving the office can confirm the office hours.

Shipping arrangements for non-routine sampling events should be included in the Quality Assurance Project Plan.

Always call the DEQ Laboratory to inform them of the incoming samples, the carrier used for shipping, the number of coolers shipped, and the shipping point.

APPENDIX A Data Validation Criteria for Water Quality Parameters Measured in the Field

DEQ04-LAB-0003-QAG

Data Quality Matrix
DEQ04-LAB-0003-QAG
Version 4.0

Oregon Department of Environmental Quality
March 09 2009
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Data Validation Criteria for Water Quality Parameters Measured in the Field

Quality Level	Quality Assurance Plan	Water Temperature Methods	pH Methods	Dissolved Oxygen Methods	Turbidity Methods	Conductivity Methods	Bacteria Methods	Data Uses
A+	DEQ QAPP approved by DEQ QA Officer	Thermometer Accuracy checked with NIST standards A ≤ ± 0.5°C P ≤ ± 0.5°C	Calibrated pH electrode A ≤ ± 0.2 S.U. P ≤ ± 0.3 S.U.	Winkler titration or calibrated Oxygen meter A ≤ ± 0.2 mgL^{-1} P ≤ ± 0.3 mgL^{-1}	Nephelometric Turbidity meter A ≤ ± 5% Standard value P ≤ ± 5% (± 1 NTU if NTU < 20)	Meter with temp correction to 25°C A ≤ ± 7% of standard value P ≤ ± 10%	DEQ Approved Methods Absolute difference between log-transformed values P ≤ 0.6 log	Regulatory, permitting, compliance (e.g., 303(d) and 305(b) assessments)
A	External QAPP	External Data Thermometer Accuracy checked with NIST standards A ≤ ± 0.5°C P ≤ ± 0.5°C	External Data Calibrated pH electrode A ≤ ± 0.2 S.U. P ≤ ± 0.3 S.U.	External Data Winkler titration or calibrated Oxygen meter A ≤ ± 0.2 mgL^{-1} P ≤ ± 0.3 mgL^{-1}	External Data Nephelometric Turbidity meter A ≤ ± 5% Standard value P ≤ ± 5% (± 1 NTU if NTU <20)	External Data Meter with temp correction to 25°C A ≤ ± 7% of standard value P ≤ ± 10%	External Data DEQ Approved Methods Absolute difference between log-transformed values P ≤ 0.6 log	Regulatory, permitting, compliance (e.g., 303(d) and 305(b) assessments)
B	Minimum Data Acceptance Criteria Met	Thermometer Accuracy checked with NIST standards A ≤ ± 1.0°C P ≤ ± 2.0°C	Any Method A ≤ ± 0.5 S.U. P ≤ ± 0.5 S.U.	Winkler titration or calibrated Oxygen meter A ≤ ± 1 mgL^{-1} P ≤ ± 1 mgL^{-1}	Any Method A ≤ ± 30% P ≤ ± 30%	Meter with temp correction to 25°C A ≤ ± 10% of standard value P ≤ ± 15%	DEQ Approved Methods Absolute difference between log-transformed values P ≤ 0.8 log	Regulatory, permitting, compliance (e.g., 303(d) and 305(b) assessments) with professional judgment
C		A > ± 1.0°C P > ± 2.0°C	A > ± 0.5 S.U. P > ± 0.5 S.U.	A > ± 2 mgL^{-1} P > ± 2 mgL^{-1}	A > 30% P > 30%	A > ± 10% P > ± 15%	Absolute difference between log-transformed values P > 0.8 log	Void data. Not used for 303(d) and 305(b) assessments
D		Missing Data	Missing Data	Missing Data	Missing Data	Missing Data	Missing Data	Missing Data
E	No QAPP provided	No Precision Checks	Any Method No Precision Checks	Any Method No Precision Checks or A ≤ ± 2 mgL^{-1} P ≤ ± 2 mgL^{-1}	Any Method No precision checks	Meter without routine calibration No precision checks	Any Method No precision checks	Informational purposes only
F	See accompanying notes							

Appendix A

Appendix A (continued).

Notes:

QA definitions of Data Quality Levels

+ – Data of known Quality; collected by DEQ; meets QC limits established in the QAPP.
A – Data of known Quality; submitted by entities outside of DEQ; meets QC limits established in a *DEQ-approved* QAPP.
B – Data of known *but lesser* Quality; data may not meet established QC but is within marginal acceptance criteria; or data value may be accurate, however controls used to measure Data Quality Objective elements failed (e.g., batch failed to meet blank QC limit); the data may be useful in limited situations or in supporting other, higher quality data. **Note:** Statistics for **turbidity, conductivity,** and **bacteria** are concentration-dependent; thus low-concentration B level data may be considered acceptable for all uses.
C – Data of unacceptable Quality; data are discarded (Void) typically in **A** response to analytical failure. **Note:** There may be rare instances where there may be field data that may still meet DQOs as determined by the Project Officer. In these cases a result should be entered instead of "Void" however the grade must remain at C. There must also be a comment in the final report that explains the qualification.
D – Incomplete data; no sample collected or no reportable results, typically due to sampling failure.
E – Data of unknown quality or known to be of poor quality; no QA information is available, data could be valid, however, no evidence is available to prove either way. Data is provided for Educational Use Only.
F – Exceptional Event; "A" quality data (data is of known quality), but not representative of sampling conditions as required by the project plan.(e.g., a continuous water quality monitor intended to collect background environmental conditions collects a sample impacted by a fire that created anomalous conditions to the environment).

Data Quality Level Grading Criteria:

A = Accuracy as determined by comparison with standards, e.g., during equipment calibration or pre- and post-deployment checks

P = Precision as determined by replicate measurements, e.g., during field duplicates, field audits, or split samples

CHAPTER 3 – FIELD COLLECTION METHODS

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SURFACE WATER SAMPLING METHODS

Background

This section describes the methods used by the Water Monitoring and Assessment (WMA) Sections to routinely collect surface water samples. The goal of surface water sampling is to safely collect the most representative sample from the water body. Methodologies described below were developed to meet the objectives of the monitoring programs discussed in earlier sections. Special studies have Quality Assurance Project Plans which may reference these methodologies or describe alternative methodologies. In general, the following methods contain field-tested procedures, which may be useful when developing study plans.

Equipment and Supplies

Surface water sampling requires specific equipment to collect water samples and perform the required field analyses in an orderly and efficient manner. Some equipment and supplies are listed below. Checklists are provided as a guide for field staff to appropriate equipment when preparing for a sampling expedition. Additional equipment and supplies may be needed when special studies or other analysis are requested and should be planned in advance.

Documents

- Data Sheets
- OHD bacteria sheets
- Run Book
- Field Notebook
- Clipboard
- Shipping forms

Sampling Equipment

- Buckets (4) Standard DEQ 4 Liter Stainless Steel
- Bucket with Secchi disk on top and knotted rope
- Bucket lid plugs, if not sampling for bacteria
- Ropes: - (2) 30 meters long
- Ropes: - (2) 10 meters long
- Van Dorn bottle with messenger (or peristaltic pump)
- Bacteria bottle holder: marked at one meter
- Phytoplankton net

Sample bottles

- DO, BOD bottles and BOD bottle caps
- Basic poly l liter (P poly)
- Nutrient poly 500 mL (R poly)
- Dissolved basic poly 250 L (DP poly)
- Bacteriological bottles (sterile)
- Bacteriological tubes (sterile)

Reagents and Supplies

- Small dropper bottle of concentrated H2SO4 (for preservation of nutrient poly)
- Dissolved Oxygen (By Winkler Titration) - See method for associated supplies.
- Alkalinity and pH- See method for associated supplies.
- Conductivity/Salinity- See method for associated supplies.

Filtering

- Glass filter jar
- Filter base & top and rubber stopper
- Hand vacuum pump (With vacuum gage for chlorophyll *a*)
- 250 mL graduated cylinder
- Filters:
    - 0.45micron membrane for dissolved metals, boron, silicon, chlorides, sulfates, or orthophosphate
    - 0.7 micron glass fiber filter for chlorophyll
- Chlorophyll *a* supplies:
    - Numbered plastic petri dishes
    - Aluminum containers for petri dishes shipping
    - Dry ice and dry ice container

Miscellaneous

- Stainless steel stirring spoon
- Tape dispenser and nylon tape
- Paper to wrap glass bottles in for shipping
- Distilled water and container
- Blank water and container
- Waste water container
- Towels
- Ice Chests, sufficient quantity to account for 50 lb. weight limit
- Wet ice
- DO saturation tables
- Calculator
- Clip board
- Field notebook
- Tide tables
- Bathymetric map
- Rain gear
- Hip boots
- Cell phone
- GPS unit

Methods

Sampling Expedition Preparation

Review project plans; make copies of proper field forms; take proper field notebooks, DO saturation tables, and basin maps. Take extra survey data sheets, and Oregon Health Division bacteriologic forms.

Consult the proper run checklist and "Duplicate Cooler Checklist" to determine what equipment is needed. Determine the number of sample bottles required from the monitoring schedule (take extra bottles for breakage, quality assurance, blanks, and additional samples). Replenish and/or bring refill bottles, of the chemicals in all reagent bottles and de-ionized water per checklists, following laboratory safety precautions. Load equipment into van. Inspect and calibrate field instruments (such as pH, SCT meters) as necessary prior to departure. All instrument checks and calibrations shall be documented in the logbooks according to specified procedures documented in the appropriate MOMs section.

Inspect vehicles for sampling equipment, safety equipment and general vehicle condition. Sign out on the computer whiteboard. Before you leave, recheck and make sure everything on the sampling checklist, van

> Expired reagents affect analytical results!
> Ensure that reagents, buffers, and standards are not beyond their expiration date (as indicated on the container, see appropriate MOMs sections for individual analyses) or otherwise appear contaminated.
> Concentrated Sulfuric Acid: Expiration date is six months from the fill date.
> Spent concentrated acids and bases should be neutralized or diluted and flushed down the deep sink with excess water: turn on a faucet in a laboratory sink and then slowly pour the chemical into the stream of water to be flushed down the drain.

equipment checklist and the duplicate cooler checklist is in the vehicle. Inform your manager or a co-worker about your itinerary. When sampling from May through October, pick up dry ice for chlorophyll.

Sampling Procedures

Parking

Drive to collection site. Park the vehicle in a safe place, preferably up-traffic from the sample site. This allows approaching vehicles to see your vehicle with warning devices prior to approaching you on the bridge. Deploy necessary safety gear. Refer to the "Bridge Zone Safety" JSA for further information.

Set up

Vehicle
Before sampling the first site each day, set up the equipment for testing in the vehicle. While one person sets up and tests the conductivity and turbidity meters, rinses the buckets and sets up the bottles, the other person should be calibrating the pH meter and preparing the dissolved phosphate bottle (DP) for filtering. Refer to the conductivity, turbidity and pH methods for further information on meter testing and calibration. Titrant left in the burettes overnight should be drained and replaced with new titrant. At each site, select sample bottles and record the numbers on the field data sheet.

Boat
If a boat is involved, follow safety procedures outlined in the safety section when launching the boat and conducting the survey. Only staff carrying the Boater Education Card may operate the boat. Take aboard all needed sample containers (including extra sample containers) to complete the survey. Returning for needed containers can nullify the run if the survey is being conducted during a specific tidal cycle.

Recommended standard procedures should be followed closely on the boat, but surface and wind conditions may interfere. On board meter readings, (i.e. pH) can be difficult with a pitching boat in rough waters. Under these conditions, some field analysis may be done after returning to shore or in the lab, within prescribed holding times.

The safety of the monitoring crew is primary and sample collection secondary. Refer to the "Working On or Near Water" JSA for further information. Knowledge of weather forecasts and observation of Coast Guard warning flags is important. A full working knowledge of maritime rules and regulations concerning boating is required. Record all pertinent observations relating to bay appearance, tidal stage (calculate tidal stage from NOAA tide tables and enter on field data sheets upon return to laboratory), etc.

Sample Collection

Bucket Grab for water
This method is used regularly on ambient sampling runs and for collection of samples at bridges or non-wadeable sites.

Use stainless steel buckets to collect the sample (Figure 1). For normal sampling, use 2 sampling buckets. These two buckets represent one sample collected within a reasonable time and space. Rinse buckets and bucket lids if they may contain contaminants from a previous use (e.g. marine water) or contact with other contaminants. One bucket is used for DO, BOD, and bacteriological bottles. The other bucket is used to collect water to measure pH, alkalinity, and turbidity, fill the basic and nutrient bottles, and filter for chlorophyll analysis and dissolved basic and dissolved metals bottles. Temperature and conductivity are taken from the bottle bucket as soon as the bottles are removed.

Record the date and time on the data sheet. Select sample bottles and record the numbers on the data sheets.

Use the bottle with the smaller number for DO and the larger numbered bottle for the BOD.
Into one bucket (the "bottle bucket") place:
2- 300 mL DO bottles,
bacteriological bottle.

The three metal tubes that extend from the bucket lid deliver water to the DO and BOD bottle. Remove the bacteriological tube from its sterile wrap and insert it through the opening on the top of the bucket and directly into the bacteriological bottle. Handle the bacteriological tube by the rubber stopper keeping the tube as sterile as possible. Likewise, handle the bacteriological bottle with care to avoid possible contamination. If no bacteriological sample is taken, plug hole to reduce aeration of D.O. samples. The metal tubes and glass bacteriological tube keep the bottles upright as well as fill and flush out the bottles.

Secure the lids of both buckets by tightening the wing nuts, and attach the rope.

Figure 1 Stainless steel sampling bucket, lid with metal tubes, and bucket with rope attached

Take ropes and buckets to collection site. Lower the buckets into the water at the most representative sampling point. Where current and depth allow, lower the bucket to 1 meter (the knots in the ropes are set at 1 meter). Do not hit the bottom or allow the bucket to plane on the water surface. If the water is less than 1 meter deep, lower the bucket to one half the depth of the water. A trail of bubbles should be visible.

Watch for termination of air bubbles to indicate when bucket is full. If the buckets were warm due to high ambient temperatures, allow extra time for filling so that bucket temperature comes to equilibrium with water temperature. Raise the buckets carefully; avoid knocking material onto the buckets. Take care to keep the ropes from getting muddy. Return to the vehicle and process samples. Collect additional samples (oil and grease, biological, etc.) if needed.

Lake/Estuary Sampling

The sample is a vertical integration of water between the surface and the Secchi depth (some sample collections may be at a discreet depth, i.e. surface, mid, bottom). Use one Secchi disc-topped bucket. Rinse bucket at the first station site to prevent contamination from previous use and load it with bottles as described in the previous section. Lower the bucket at a constant rate through the water column until Secchi reading is made. Correct the reading for angle of rope and avoid hitting the bottom.

Watch for termination of air bubbles to indicate when bucket is full. Avoid planing or dragging the bucket to reduce aeration of the DO sample. The boat should be drifting with the tide to help avoid planing. Retrieve the bucket and place on boat deck for sample bottle removal.

Hand Grab for water

This method is used regularly for collection of samples at sites without bridge access or where sampling from the bridge is hazardous. Select sample bottles and record the numbers on the data sheets. Use the bottle with the smaller number for DO and the larger numbered bottle for the BOD. Record date and time on the data sheet. Take the bottles to the site.

WADE INTO THE WATER WITH CAUTION (SEE FIGURE 2). Walk upstream and collect sample facing upstream. Look for areas where the water is well mixed. Sample above tributaries and other discharges, or far enough downstream to assure thorough mixing. Grab samples used for auditing continuous monitoring devices should be collected as near to the device as practical without disturbing the equipment. Avoid disturbing and suspending bottom sediments.

Invert one bottle at a time, place each under the surface about 18 inches or half way to the bottom and gently rotate the bottle to fill. Cap the bottle while still submerged. Attach the BOD bottle cap while still submerged. If a single bottle is being used for collection of pH and conductivity samples, rinse the bottle in the site's water three times before filling. Temperature should be taken immediately at the site.

Figure 2 Field Safety: Wading

No sample is worth endangering your self or co-workers. When wading always work with a partner and follow these guidelines. Refer to the "Working On or Near Water" JSA for further information.

- Wear personal flotation devices when wading in streams with depths over your chest or fast velocities.
- Wear appropriate foot wear and move slowly checking for unstable substrate or unexpected holes. A wading rod can be used to help assess streambed conditions.
- Use caution when wading in streams with swift current. As you get deeper your ability to keep a grip on slick substrate will be reduced and you may be pushed off your feet by slower velocities. Even shallow water at high velocities can be dangerous. Do not attempt to wade in a stream for which values of depth multiplied by velocity equal or exceed 10 ft^2/sec.
- Avoid hip boots that are tight around the ankles and waders that are tight around the chest—these may be difficult to remove in an emergency situation. Be aware of the possibility of slipping and going underwater (feet up, head down) while wearing them. Wear a hip belt with waders to help prevent filling the waders with water.
- Watch for changes in river stage, especially when working downstream from a control structure. If working directly below a dam, contact the gate operator before entering the stream.
- Watch for sand channels that can shift under foot and become quicksand.

Van Dorn Bottle for water

This method is usually used for estuary or lake sampling at prescribed depths, depending on project objectives. Rinse sampler with DI water. Pull back the stoppers and set the trigger mechanism. Since the triggering devices are sensitive, don't jolt the sampler. Gently lower the sampler to the desired depth and send the messenger down the line to trip the trigger. Raise sampler to surface. From each depth, fill water sample bottles for lab analysis, test pH and alkalinity, and fill DO bottles if using Winkler method. When filling the DO bottles, insert the tube to the bottom of the bottle. Fill from the bottom up to avoid aeration. Store all water samples in a closed cooler on ice until delivery to the lab.

Peristaltic Pump for water
This method is used mostly for estuary, lake, or intergravel DO sampling. Use peristaltic pump to collect water from the prescribed depth for water column samples. Additional samples from other depths or integrated samples from similar water levels may be collected (depending on project objectives). Connect pump to power source (internal power/recharge source or outside power source). Lower the intake line to desired level below water's surface. Secure the discharge line for disposing of water during the purge. Start the pump and regulate the flow to avoid aeration by adjusting the rheostat knob on the control panel. From each depth, fill water sample bottles directly from pump tubing or through a filter for lab analysis, test pH and alkalinity, and fill DO bottles if using Winkler method. Store all water samples in a closed cooler on ice until delivery to the lab.

QA Sample Collection

Samples are defined by the place and time where some environmental media was collected for analysis or where an observation is made about the environment. When QA duplicate samples are taken, the primary sample is collected first and the duplicate is collected afterwards. Containers are subsamples that represent a whole sample. We collect the duplicate sample to measure precision between samples, not between subsamples.
Collect a QA duplicate sample once per sampling expedition or every 10 % of samples, whichever is more. Duplicate samples should be collected as discrete samples—i.e. a bottle bucket and empty bucket should always be lowered at the same time.

When four buckets are available, load one of the first pair of buckets with bottles designated for the regular sample. Load one of the second pair of buckets with bottles designated for the duplicate sample. Carry both pairs of buckets to the bridge. Lower the first pair of regular sample buckets (one with bottles, one without), collect the sample and raise the buckets back onto the bridge. Then repeat the sample collection with the pair of duplicate buckets. Return to the vehicle with both pairs of buckets and process the samples.

If only two buckets are available, collect a complete sample using both buckets, return to the vehicle and process the sample. Prepare the buckets again, return to the bridge with the buckets and repeat the sampling for the duplicate field measurements and duplicate containers.
If field measurements of the duplicate sample do not agree with those of the "primary" sample, reanalyze the duplicate (and/or primary) sample to confirm or deny the disagreement in results. Note the re-measurement(s) on the field data sheet; do not cross out the original results.
One equipment blank sample should be collected during a sampling expedition. When sampling from buckets, pour blank water into the buckets and fill sample bottles from bucket.

Sample Processing

The sample processing method described below is the standard method for the Ambient Water Quality Monitoring Network. Generally, two staff members conduct ambient sampling. The sample processing on an ambient run is divided into two jobs. An outside person is stationed outside of or away from the mobile

lab and prepares the samples for filtering, pH/alkalinity titration, and DO titration. The outside person also measures sample temperature, specific conductance/salinity and turbidity. The inside person is stationed within or at the mobile lab and filters the sample and measures sample pH, alkalinity, and DO. This procedure must be modified slightly if sample containers were filled directly from the water body. See the discussion above on "Hand Grab for water".

Outside person
If the samples were collected by bucket, remove lids. Be careful and avoid dropping anything into the buckets.

From the bucket without bottles, rinse the graduated cylinders with sample water and fill the 100 mL graduated cylinder with 100 mL of sample for pH and alkalinity determinations. Fill the 250-mL cylinder with 250 mL of sample for dissolved ions and chlorophyll filtering.
Place stoppers in DO and BOD bottles while they are still in the bucket. Remove bacteriological bottle from bottle bucket; pour out 1/2 to 1 inch of water from bottle and cap. Remove DO and BOD bottles.

Prior to placing the BOD bottle in the cooler, the bottle must be capped with the BOD cap that is filled with sample water to prevent contraction of the sample and replacement with air. Attach BOD cap prior to removal of bottle from the bucket or by filling the cap and inverting the BOD bottle onto the filled inverted cap (make sure the BOD stopper is tight).

Rinse conductivity probe and place in bottle bucket after bottles have been removed. Allow approximately 30 seconds for the temperature of the probe to equilibrate with the sample. Call out temperature and specific conductance or salinity readings for the inside person to record. Turn off S-C-T meter.
Prepare DO bottle according to DO method.

Stir the sample prior to filling bottles or the turbidity cell. The sample may be stirred using a stainless steel spoon or rubber spatula. If neither is available, fill the 1-liter polyethylene container (P-poly) and then rapidly dump the P-poly back into the sample to mix the sample.

Fill the P-poly and the 500-mL polyethylene container (R-poly). Add 12 drops of concentrated H_2SO_4 to the R-poly to reduce the pH to less than 2.0 SU.

Measure turbidity from the bucket without the bottles (See turbidity methods for details).
Save remainder of water until pH and alkalinity determinations have been made, for possible secondary testing and for probe rinsing/ soaking.

Inside person
Measure pH and titrate alkalinity on the 100-mL sample (see pH and alkalinity method). Rinse probe and beaker thoroughly. Pour additional sample into the beaker and suspend the probe in the sample while traveling to the next site. If the pH probe is not responding well, recheck the pH value upon arrival at the next site. If the value differs with initial reading by more than +/- 0.3 SU, recheck pH using the P-poly or request a lab pH on the field sheet. If the meter continues to behave poorly, switch to the back-up meter.

Filter samples for dissolved ions, (primarily ortho-phosphate, but can include boron, chloride, fluoride, iodine, hardness calculated from common cations, silica, and sulfate). Rinse the filtering apparatus with distilled water (rinse well if previous site was marine water) and insert the 250-mL polyethylene container (DP-poly) without lid into filtrate receiving jar. Attach graduated filter funnel to top of jar, ensuring that the bottom of the filter funnel tapered spout is inside of the DP-poly. With Teflon tweezers, place a 47-mm

0.45mm-micron membrane filter in filtering apparatus, being careful not to contaminate the filter with your fingers. Dissolved phosphates samples are to be filtered through a 0.45mm micron membrane filter. Attach the magnet-based funnel onto the filter base. Pour the 250-mL sample into the funnel. Draw a vacuum using the hand pump. Do not exceed 30 in. Hg. Continue to draw a vacuum until the sample has filtered into the DP-poly.

Occasionally the sample will have a large amount of suspended solids that will make filtering difficult and more than one filter will be needed. Through visual inspection of 250 ml sample determine if entire sample will be able to be filtered or if it is necessary to change filters mid way through sample. If sample is turbid filter only a portion of the 250 ml sample then, release the vacuum, remove the graduated funnel top from the jar, use Teflon tweezers to remove old filter and replace with new filter, while keeping the funnel tapered spout the DP-Poly inside funnel base, reattach filter top to jar and repeat filtering process. When the entire sample has been filtered, release the vacuum from the jar; remove sample bottle, cap and place in cooler. Remove filter from filtering apparatus and rinse funnel. Cover apparatus top with plastic lid until used.

Filter samples for chlorophyll. If processing the sample for chlorophyll *a*, place 0.7 micron glass fiber filter (GF/F) in the filtering apparatus. Draw a vacuum using the hand pump to 6 in Hg do not exceed 6 in. Hg as it will cause the cells damage. If present, remove the DP bottle from jar. Replace filtering apparatus and add 1mL of super saturated Magnesium Carbonate. To create super saturation, shake the container of Magnesium Carbonate, let settle slightly and obtain 1 mL from the clear part of the solution. Draw a vacuum using the hand pump to remove excess solution through the filter. Remove the chlorophyll filter with Teflon tweezers and place filter in a labeled plastic petri dish and store in the aluminum container on dry ice. Ensure that the aluminum container is labeled (duct tape is fine) with survey name, date, and your initials. Thoroughly rinse filter apparatus with DI water.

Filter samples for dissolved metals. To process a sample for dissolved metals, repeat the standard filtration procedure using a 250-mL DM (dissolved metals) bottle and a 0.45 micron membrane filter. Put on PPE (eye protection and gloves), and preserve the sample with 25 drops of concentrated nitric acid (HNO_3)to achieve a pH end point of 2 S.U. or below and place in the cooler. **Do not use the 0.7 micron glass fiber filter (GF/F) for this process!**

Titrate DO sample (see DO methods).

Calculate percent Saturation for DO (see DO methods)

GROUNDWATER SAMPLING METHODS

Background

The objective of this section of the Methods of Operation Manual (MOMs) is to provide general reference information for groundwater sampling. These procedures are designed for the collection of samples used to characterize groundwater, and to identify contaminants in groundwater. Every effort must be made to assure that the sample collected is representative of the groundwater being sampled.

Groundwater sampling involves the collection of representative samples of groundwater from wells, seeps and springs. This section will cover the collection of samples from wells. The collection of samples from seeps and springs is covered elsewhere in the Methods of Operation Manual (see the Surface Water Sampling Methods section).

Two types of wells commonly sampled. The first type is the production well, which includes domestic, industrial, municipal and irrigation wells. These wells have pumps permanently installed, and are in use on either a continuous or intermittent basis. Production wells are not drilled or constructed as groundwater monitoring wells, but can often be used as such. Their primary purpose is to provide water at quantities sufficient to meet the needs of the user(s). The second type of well is the monitoring well, which are installed specifically for the monitoring of groundwater. These wells may or may not have pumps permanently installed. Groundwater is removed from the well on a periodic basis to collect samples for chemical analysis.

Groundwater sampling basically consists of two steps:

1. Purging the well and/or delivery system of unrepresentative water.
2. Collection of representative samples.

Purging consists of flushing the delivery system between the well and sample point to assure that the sample is representative. Production wells generally do not need to be purged of large quantities of water to assure the collection of representative samples. Generally, the use of these wells as water supply sources results in a constant re-supply of fresh groundwater into the well.

Monitoring wells, on the other hand, generally require purging to remove stagnant water from the well casing. Purging can be done with bailers or pumps. The purge volume required to obtain representative groundwater is variable, depending on a number of factors, including well design and construction, and groundwater flow rates. The WMA Sections have found that removal of three well casing volumes is often adequate to obtain representative groundwater samples. However, field personnel must determine the volume for adequate purging. Field parameter measurements are taken during purging to help determine when representative groundwater is available to sample.

Monitoring wells can be purged with bailers or pumps. The choice of purge equipment will depend on a number of factors, including sensitivity of samples being collected, depth of well, diameter of well, volumes to be removed, screen interval, completeness of well development, restricted rate of water withdrawal, and impact on cone-of-depression.

Once purging has been completed, sampling is done with equipment designed or adapted to collect a representative groundwater sample. The sample equipment need not be the same equipment as was used for purging. As with purging equipment, care should be taken in choosing the correct sampling device, making sure the device will not affect sample integrity.

The traditional purging of three or more casing volumes may not be necessary at all monitoring wells. Methods that require little or no purging may be appropriate at some wells. These methods include passive sampling (no purge) and low-flow sampling. Passive sampling assumes representative groundwater is present in the well, so purging is not required. Low-flow sampling removes water at low flow rates until field parameters are stable; indicating that representative groundwater is present. Special requirements must be met for either of these methods. Passive sampling is not currently employed as a method by the WMA Sections, and will not be discussed further. Low-flow sampling is further discussed below.

Appropriate sample containers and preservation methods need to be determined well in advance of sampling. The DEQ Laboratory "Field Sampling Reference Guide" provides complete information on container types and preservation requirements.

Interferences and Potential Problems

The primary goal of groundwater sampling is a representative groundwater sample with minimal alteration. Sample integrity can be compromised in many ways, including (1) collecting an unrepresentative sample (example: inadequate purging); (2) incorrect handling of the sample (example: samples not preserved); or, (3) improper sampling process (example: air bubble left in a volatile organic sample). There are numerous ways of introducing foreign contaminants into a sample during collection and storage. These must be avoided by following strict sampling procedures and using trained field personnel.

Some causes of an unrepresentative groundwater sample:

Physically damaged wells or sampling equipment.

Well water highly turbid from faulty well installation or development.

Well casing or sampling equipment constructed of material affecting the chemical quality of the sample.

Poor documentation of design and construction of the well. This information is needed to establish the proper sampling point and to calculate appropriate purge volumes.

Incorrect collection point in the well (example: purging from the screen zone and then collecting sample at the upper well casing water level).

Incorrect or inadequate purge volume.

Purge flow rates that are too high (especially exceeding rates used during development). This can cause excessive drawdown , mixing of water from distinct vertical zones and may increase sample turbidity

Aeration of sample.

Improper sample preservation.

Cross contamination between wells or from other outside sources introduced on improperly decontaminated equipment. Inadequate rinsing of decontaminated equipment can also introduce contaminants from detergents or chemicals used in the decontamination procedure.

Knowledge of the site and the correct purging and sampling techniques is important. Professional judgment often needs to be used in determining proper purging and sampling methods, and when corrective action is needed.

Documentation

Field documentation is important for maintaining integrity between sampling goals and sample analysis. Each phase of collecting a sample requires documentation, which may include the following:

sampling checklist

field/analysis request sheet

field instrument calibration notebook

bound field notebook

chain-of-custody forms (if required)

inspection worksheets (RCRA inspections)

The ***Sampling Checklist*** lists all sampling equipment and needs for conducting a groundwater survey. The checklist assures that all survey equipment (pumps, meters, buffers, containers, etc.) are packed for the sampling event.

The ***Field/Analysis Request Sheets*** contain information necessary for identifying site samples and conveying information to the laboratory staff to ensure correct analysis is performed on each sample. The following information is needed on all field sheet formats:

Agency header

Project title

Sampling Event number

Fund code

Field staff names

Site name

Site identification number (STORET and/or LASAR number)

Sample bottle numbers

Year/month/day

Time of sample collection

Analysis required (if not specified in a QAPP or SAP)

Comments on factors directly affecting the condition or potential alteration of a sample, i.e. turbidity, contamination, preservation, or misidentification.

A ***Field Instrument Calibration Notebook*** is kept for each field instrument: specific conductance, pH, and oxidation-reduction potential and dissolved oxygen meters. Each instrument must have its own notebook for recording calibrations, checks, and maintenance.

Bound Notebooks are used to record all field observations on site conditions at the time of sample collection. Field notes are important to convey information about the site to project participants and for future field activities at the site. Information in the notebooks may include physical changes to the site, site contacts, weather conditions, sampling equipment needs or any site-specific problems encountered with sampling.

The ***Chain-of-Custody Form*** is used to record sample custody more completely than the "field/analysis request" forms. These forms are used when legal issues are involved. For current procedures, see the DEQ Laboratory Field Sampling Reference Guide.

Inspection Forms are found in several formats and are used to evaluate facilities under State permit. The forms are worksheets used to document conditions observed on site and to reference when writing evaluation reports.

Pre-Sampling Procedures

Prior to actually collecting a groundwater sample, three procedures must be followed unless otherwise specified in a QAPP or SAP: (1) well identification and examination, (2) measurement of water level elevation, and (3) well purging , while monitoring one or more of the following parameters: temperature, pH, specific conductance, dissolved oxygen and/or oxidation-reduction potential.

Well Identification and Examination

Conduct the following inspection and record all field observations in a bound field notebook, or on a well site identification sheet. Prior to sampling, obtain the proper authority and permission to access the well site, and to follow any security system procedure in place.

1. Locate the well from site notebook maps, descriptions, etc.
2. Check for a well identification label.
3. Inspect the well for security devices and protective systems that may be in place. Record the type of security and protective devices in place for future access.
4. Inspect outside protective casing, pad, and immediate area for damage, standing water, etc.
5. Access well and inspect inside area of well casing and protective outer casing. Look for damage, evidence of water intrusion, standing water, etc.
6. Locate reference marks for water level measurements. The reference mark should be on the inner well casing.
7. If the well is new, take pictures of the well site and obtain latitude and longitude position reading with a Global Positioning System (GPS) instrument, or as a backup, from a USGS map, preferably at a scale of 1:24,000 (7-1/2 minute quadrangle). Record the latitude and longitude on the field data sheet and indicate the well is new.

Water Level Measurement

Measuring static water level elevations on a regular basis is important for determining whether horizontal and vertical components of the hydraulic gradient have changed since initial site characterization. Static water level measurements are also required to construct a map of the site's uppermost aquifer, depicting its potentiometric surface. A change in groundwater flow direction may necessitate modifying the design of the groundwater monitoring system.

Water level measurements are used for:

Understanding groundwater recharge

Constructing potentiometric surface maps

Calculating hydraulic gradient between wells

Understanding draw down influences from surrounding wells

Calculating purge volumes.

Depth-to-bottom measurements are used for:

Well identification

Verification of well log information

Monitoring for silt build-up in the well

Calculating purge volumes.

There are various measuring devices and methods used to collect water level measurements. Although several different types of devices are found in our equipment storage, the electronic sensor is the preferred measuring device. The types that may be used or encountered in the field include:

Electronic tape

Stainless steel tape with carpenter's chalk (wetted tape method)

Weighted tape (plunking method)

Float-type device

Pressure transducer

Acoustic well probes.

Operator error can compromise the accuracy and precision of these various devices. Regardless of the type of equipment used, the field investigator needs to know and understand how the equipment works. In most cases, the accuracy of the measurement needs to be one one-hundredth of a foot (0.01-foot), which requires experience and careful use of the measuring device.

Although the measuring tape can be used with reasonable accuracy and precision, the best choice is the electronic sensor for obtaining water level measurements. Both types of measuring devices are discussed below. Available equipment includes:

YSI specific conductance/temperature/water level sensor. This meter has a 1" diameter probe, with visual digital readout.

Slope Sensor. The probe is 3/8" diameter, with an audible and visual responder.

M-scope.

Engineer's tape.

ELECTRONIC SENSOR

1. Water levels should be taken prior to purging. If the well has been purged recently, water levels in the well should be allowed to recover for a minimum of 24 hours before the well water level is checked. In low yield aquifers, recovery may take longer than 24 hours. If necessary, several water level measurements should be made over a period of several days to ensure recovery to static, ambient conditions has occurred.
2. If the inner well casing cap is non-vented, the well should be allowed to equilibrate after removing the cap and before taking the water level measurement. This may take time, so several readings will be necessary to obtain the point of equilibrium.

3. The water level should be measured from a surveyed datum point on top of the inner well casing. If no reference point is marked on the casing, then take the highest point on the casing as the reference point. Mark that point for future reference. Never use the outer protective housing. If a new reference mark is needed, record details in the field notebook. Record measurements to the nearest 0.01-foot.
4. Water level measurements from bore holes, piezometers, or monitoring wells that will be used to define the water table or a single potentiometric surface should be made within 24 hours of each other. In certain situations, water level measurements should be made within an even shorter time interval. These situations include:

   wells located within a tidally influenced aquifer

   aquifers affected by river stage, bank storage, impoundments, and/or unlined ditches

   aquifers stressed by intermittent pumping of production, irrigation, or supply wells

   aquifers being actively recharged because of recent precipitation
5. Frequent inspection for deterioration of the cable and cable markings must be done.
6. Water level measurement equipment should be decontaminated prior to use. Device line and probe surface contact is minimal, but care should be taken to clean the line with distilled water during withdrawal from the well. Alcohol and other cleaning reagents may deteriorate the cable and lead to cross contamination.
7. Check the sensor, probe and line for damage. Never use a sensor with a broken or torn cable.
8. Lower the measuring device cable into the well until contact with the water surface is made. At the audible and/or visual response, pinch the cable with forefinger and thumb against the reference point. A permanent mark should be visible for this point of measurement. Use a tape measure marked in hundredth-foot increments to measure any unmarked cable section to obtain greater accuracy.
9. Repeat the measurement again to assure accuracy.
10. Withdraw and clean the sensor cable with distilled water. Generally, one person will reel in the cable as the other person squirts distilled water onto the cable directly, or allows the cable to be pulled through a clean towel moistened with distilled water.
11. Record measurements on the field data sheet and in the field notebook.

CHALKED ENGINEERS TAPE

Engineer tapes are capable of acceptable accuracy when used properly. The procedure requires the use of a weighted tape and chalk. The chalked tape is generally more accurate than the weighted tape/plunking method.

1. Chalk several feet of the tape at the weighted end.
2. Lower the chalked tape to the surface of the water, trying not to touch the side of the well casing. The tape should hang freely.
3. Listen for the chalked end to touch the water, and then allow the tape to enter the water beyond the chalked end.
4. Read the tape at the reference point on the well casing and withdraw the tape, trying to avoid dragging the tape against the well casing wall.
5. Read the chalked end of tape where the chalk has been moistened or removed. Subtract the amount of tape that was submerged from the tape measurement at the reference point.

6. Record the water level measurement on the field data sheet and in the field notebook

WEIGHTED ENGINEERS TAPE

The weighted tape method (plunking) can be as accurate as other types of measuring devices, but is the most difficult to perform without practice. This method is the least favored of the methods discussed, and should not be used unless more effective equipment cannot be obtained.

1. Lower the weighted tape to the surface of the water, trying not to touch the side of the well casing. The tape should hang freely.
2. Listen for the weight on the tape to touch the water. Raise the tape and allow it to drop again. Do this several times, checking the measurement at the reference point to obtain a feel for your precision. If you are working with someone, have this person repeat the procedure.
3. Record measurements on the field data sheet and in the field notebook.

Purging Monitoring Wells

Stagnant, standing water in the monitoring well casing is not representative of the formation water. Purging is the removal of this stagnant water prior to collection of groundwater samples. Purging a well is intended to assure that samples collected from the well are representative of the groundwater. It is important to use the most effective procedure to obtain representative groundwater from a well, without interfering with natural conditions surrounding the well bore hole. Due to the artificial setting created by well drilling and the disruption of the formation matrix, there are a number of opinions on how best to purge a well. The various methods for preparing a well for collecting a representative groundwater sample will be discussed to assist in choosing the correct method. The overall goal is to achieve minimal drawdown during purging with the least disruption of the surrounding matrix.

The well is purged of a specified purge volume (usually three casing volumes). Field parameters are measured during purging, generally after each casing volume is removed. Field parameters should be stable over two consecutive measurements prior to sampling (see below for stability criteria). If field parameters are not stable, then more purging may be required. If samples are collected before field parameters have stabilized, it should be noted on the field data sheet and in the field notebook.

The field parameters used to determine stability during purging always include temperature, pH, and specific conductance. Dissolved oxygen may also be included. Oxidation-reduction potential is not used.

Table 1 Parameter Stability Criteria Traditional Purge

Parameter	Criteria
Temperature	± 1 Degree Celsius
pH	± 0.3 pH units
Specific Conductance	± 10 %
Dissolved Oxygen	± 1.0 mg/l

Field parameters are defined as stable when two consecutive measurements do not exceed the criteria listed above (**Table 1**).

Purging of groundwater monitoring wells is usually done with either a pump or a bailer. There are several types of pumps available for purging.

Discussion on the types of equipment used for purging and collecting groundwater samples can be found in the Purge and Sample Equipment section.

The following general considerations apply, regardless of the purge and sample methods used:

1. Measure the static water level, as described in Water Level Measurement.
2. Calculate the volume of water in the well casing using the water level measurement, the total depth of the well obtained by field measurement (or from the well log), and the diameter of the well. The total purge volume will generally be three times the volume in the casing.
3. Select equipment for the purge. Equipment need not be the same for both purging and sampling. If the equipment is not dedicated or new disposable, assure that the equipment has been decontaminated, and that an equipment blank is collected for quality control.
4. When bailers or non-dedicated pumps are used for purging, evacuation of the water should be from the uppermost portion of the water column. This assures that all of the stagnant water in the casing is removed. It also helps minimize turbidity that may occur by stirring up sediments from near the bottom of the well.
5. The purge flow rate should ideally be no greater than the velocity with which water can flow through the well screen, under non-turbulent, laminar flow conditions. This minimizes drawing water from zones above or below the well screen section.
6. For pumps, the purge volume can be estimated by timing the rate of purge water discharge into a calibrated container. The flow rate should be checked periodically, since the flow rate may change if drawdown occurs. For bailers and pumps, the quantity of purge water removed can be measured in a calibrated container.
7. Avoid disposing of purge water around the well casing, to prevent infiltration of purge water back down along the casing.

Pumps and bailers are used for purging and sampling groundwater wells. There are several types of pumps available. Pumps may be permanently installed in a well (dedicated), or portable. Portable pumps require decontamination between wells if the well water comes in contact with pump components.

This part of the manual will cover the use and operation of the equipment the Department owns, and equipment that might be encountered in the field. Each piece of equipment has its own operational requirements and limitations. Understanding the operation will help you select the appropriate type for purging and sampling.

Assure that the equipment does not negatively affect sample integrity. Some pumps described in the following text will influence volatile organic samples, and may cause precipitation of certain dissolved constituents (metals) in the sample. Select the appropriate purging and sampling equipment for the samples to be collected (EPA, 1991b, p. 32).

The bailer is a tubular grab sampler, designed to accommodate a wide range of use in a sampling program. It is constructed of various materials (Polyethylene, PVC, Teflon, stainless steel, etc.), and comes in many diameters and lengths. Bailers may be pre-cleaned and disposable, dedicated to a particular well, or decontaminated and re-used. The bailer is fitted with a check valve at the bottom. The standard bottom check valve bailer is lowered into the well by new line, either monofilament, multi-strand nylon, or other inert material.

Bailers can be more efficient at purging than pumps in some applications. They can also be used to sample after the well is purged with a pump. It is a good idea to consider the amount of water to be removed and the pump capability (gallons per minute) before selecting equipment.

PURGING AND SAMPLING WITH A BAILER

Advantages:

Most bailer materials are inert.

No power source is needed.

Inexpensive and easy to dedicate at a large number of sample points.

Minimal out-gassing of volatile organics if a flow-reducing bottom emptying device is used.

Rapid, simple method for removing considerable volumes of purge water.

Removes stagnant water first.

Acceptable for collecting most types of samples.

Disadvantages:

Labor intensive, especially in large wells.

Both accuracy and precision are highly subject to operator error. (May cause increased turbidity and sample aeration/agitation).

In-situ parameter monitoring not possible.

Micro purging not possible.

Types available: Polyethylene, stainless steel, Teflon, and PVC.

Operation components: Line for suspending bailer, bailer retriever, and bottom-emptying attachment

PURGING WITH A BAILER

1. Select a bailer with the largest capacity accommodated by the well diameter. A large capacity bailer will maximize the purging efficiency with the bailer. Bear in mind, however, that too large a bailer can be impractical or impossible for a person to handle. Generally, bailers greater than 3-inches in diameter are impractical for use.
2. Secure the bailer by line (inert to sample type). Lower the bailer slowly to a point of collection below the water level. Do not allow the bailer to drop or to be lowered rapidly, to avoid surging at the screen and creating turbidity problems.
3. Allow the bailer to fill from the bottom until the bailer top is fully submerged.
4. Raise the bailer to the surface and pour the water into a calibrated container.
5. Continue until the calculated purge volume is removed and field parameters are stable.

SAMPLING WITH A BAILER

1. Select a bailer with the largest capacity that will be accommodated by the well diameter, and small enough for a person to handle. A large capacity bailer will avoid the need for several bailer retrievals to fill a sample container. This will reduce the chance for sample contamination by repeated handling (opening and closing) of the sample container.
2. Secure the bailer by line (inert to sample type). Lower the bailer slowly to a point of collection below

the water level. Do not allow bailer to drop or to be lowered rapidly, to avoid surging at the screen and creating turbidity problems.

3. Allow the bailer to fill from the bottom until the bailer top is fully submerged.
4. Discard the first bailer full of water to rinse the bailer. Sample collection starts with the second bailer retrieval.
5. Collect samples from the bottom valve when possible. Pouring from the top will affect some parameters more than others. Aeration will affect volatile organic samples, and may affect metals that can be precipitated out. Volatile organic compounds should always be collected using a flow reducing, bottom-emptying device.

PURGING AND SAMPLING WITH PUMPS

There are several types of pumps that can be used for purging and sampling monitoring wells. The following types will be discussed here:

Bladder pumps

Submersible pumps

Peristaltic pumps

Suction pumps

Pumps can be permanently installed in a monitoring well (dedicated). The bladder pump is the type of pump most commonly installed. Submersible pumps may also be dedicated. Peristaltic and suction pumps are not dedicated, although the tubing used may be dedicated.

Pumps may be used for purging and sampling, or for purging only. Some pumps are not suitable for the collection of certain types of samples (EPA, 1991b, p. 32).

When a pump is used for purging only, samples are collected with a bailer. Since the bailer collects samples from the top of the water column, it is important to place the pump intake near the top of the water column. This ensures that the stagnant water in the well casing is removed during purging, and that representative groundwater samples are collected.

BLADDER PUMPS (DEDICATED)

Bladder pumps are submersible mechanisms consisting of a flexible membrane (bladder) enclosed in a rigid housing. The internal bladder can be compressed and expanded under the influence of air or an inert gas, such as nitrogen. The bladder prevents any contact between the sample water and the air or gas used to operate the pump. A strainer or screen is attached on the intake side of the pump to filter out any material that could clog the check valves located above and below the bladder. Water enters the bladder through the lower check valve. Compressed air or inert gas is injected into the cavity between the housing and bladder. The bladder is compressed, and the sample is transported through the upper check valve and into the discharge line. The upper check valve prevents water from reentering the bladder. The pressure is released, the bladder refills, and the process is repeated to cycle the water to the surface. Automated control systems are available to control gas pressure and pressurization cycles. Pumping rates vary, depending on the depth of the pump, but can average between 1 and 2 gallons per minute (gpm).

Advantages:

Maintains integrity of sample, i.e. minimizes aeration, degassing, etc.

Flows can be adjusted.

Easy to use.

Good for relatively deep wells (up to 1,000 feet).

Low maintenance.

Can be used for collecting both organic and inorganic samples.

Disadvantages:

Flow rates drop with depth and may be too low for deep-well or high-volume purging applications.

Bladder is susceptible to damage by sand if inlet screen is not used. Pump mechanisms can fail, requiring expensive, time-consuming service.

Bladders or air lines may develop leaks.

Operating costs can be high if compressed gas cylinders are used.

Type used: Well Wizard

Operation components: Compressor and control box, toolbox with spare parts/tools/accessories, gas, oil.

Attachments: Disposable filters.

Operating the Well Wizard

Specific operating instructions are in the manufacturer's instruction manual. General operating suggestions and observations include:

1. Inspect well site, casing, well cap, and the pump unit fittings for damage. Check to see if a packer is installed.
2. Measure water level after well site inspection.
3. If the well has a packer installed (see well packer section, below), connect the pressure gauge attachment and air line to the compressor control box panel.
4. Packer unit inflation: Start the compressor and regulate the air flow at the pressure gauge attachment. Open the valve knob on the pressure gauge stem slowly until the compressor inflates the packer unit. Monitor the pressure gauge reading during compressor cycles until the desired pressure is achieved (approx. 90-100 psi). The packer may be damaged if the pressure is too high.
5. Close pressure gauge valve knob and watch for any loss of pressure. If pressure loss occurs, check valve knob to ensure closure. If loss still occurs, the packer may be leaking.
6. Disconnect the air line from pressure gauge stem and attach it to the bladder pump inlet valve.
7. Adjust compressor panel refill and discharge settings according to the guide on the control box panel. Make minor adjustments to the setting until an optimum discharge rate is obtained.
8. Record the refill and discharge settings in the field notebook, for future reference.
9. During compressor operation, press the moisture relief valve occasionally. Compressor operation will slow down as moisture builds up.
10. The pressure may need to be reduced for sample collection, especially for volatile organic compound samples and filtered samples.

Well Packers

A packer assembly provides a means to isolate and sample a discrete interval in the well. Pneumatically activated packers are wedged against the casing wall, isolating the well screen assembly, to minimize purging volume. The packers are inflatable, allowing for vertical placement within a well. Packers are usually constructed from some type of rubber or rubber compounds, and can be used with dedicated submersible pumps, such as the Well Wizard.

If pumps are operated at a low enough rate, a packer assembly allows sampling of a low yield well without difficulty, and minimizes the collection of turbid samples. A packer minimizes purge time and water. However, if a packer partially deflates it may allow water from above the packer to pass by the packer, which is likely to alter the water chemistry of the samples.

Electric Submersible Pumps

Variations include centrifugal type with rotating impellers, and positive displacement designs with gear rotors and progressive cavities. These submersible pumps are designed to be portable and easily serviceable in the field. A gear drive pump operates by using a small, high efficiency electric motor that is located within the pump housing. The electric motor rotates a set of gears from an intake screen atop the pump. The water is drawn through the gears and driven through a discharge line to the surface. Depending on the motor requirements, a portable generator or a battery is used to power the pump. Pumps can be operated in relatively deep wells. Pumping rates range from about 1 gpm for 12-volt submersibles, up to 60 gpm for 4-inch diameter submersibles.

Advantages:

High lift capacity for deep wells.

Relatively high pumping rate (rate decreases with depth).

Can be used in small diameter wells.

Portable or dedicated.

Reliable.

No priming required.

Flow rates can be adjusted on some models.

Disadvantages:

Highly turbid wells can damage gears.

Requires power source (line power or generator).

Potential for affecting organic analysis from the plastic internal parts and lubricants of the pump.

Discharge water temperature may be increased, which could affect some samples.

Decontamination required if not dedicated.

High Capacity Submersible Pumps

The Redi-Flo2 submersible pump has a wide use application because of its controlled flow and high discharge rate. The pump is easy to use, and operates with either a 220-volt or 110-volt power source by

just switching control boxes and generators. The 220-volt generator should be used in deep well applications (generally those wells deeper than 150 feet).

Type Available: Grundfos Redi-Flo2.

Operation components: Gasoline powered generator, 110 or 220 volt, gas, and oil.

Attachment: Disposable cartridge filter.

The following suggestions and recommendations are for the operation of the Redi-Flo2 pump:

1. Lower the pump to the desired level in the well and secure the pump support line.
2. Connect the pump power line to the control box, and connect the control box power line to available line power, or to the generator power source.
3. Select the control box panel settings for purge or sampling procedure.

12-Volt Helical Rotor Electric Submersible Pumps

The helical rotor electric pump is a submersible pump consisting of a sealed electric motor that powers a helical rotor. Centrifugal action of the rotor assembly forces the groundwater up the discharge line. Due to the gas engine's proximity to the well, VOC samples could be compromised (false positives from gas fumes). These pumps also have metal internal parts that could contaminate the sample with metals.

Flow rate is not adjustable. Consequently, the pump discharge exceeds recommended flow rates for filling VOC purge vials. This pump is also contraindicated for low yield wells, because it could purge the well to dryness quickly. Pumping rates vary depending on the depth of the well, and the pumps can be operated in relatively deep wells. A considerable amount of agitation can occur when operating this kind of pump at high rates. This may alter the sample water chemistry. In addition, high pumping rates can draw sediments from the formation, normally immobile under ambient groundwater flow conditions, into the well, resulting in the collection of unrepresentative samples (false positives for turbidity, total suspended solids, and total metals). Also, purging a well to dryness in this manner would lead to unrepresentative results for such constituents as dissolved oxygen and oxidation-reduction potential.

DEQ recommends that helical rotor pumps be used to purge high-yield wells, and that they are not to be used for sampling purposes. The pump could be used for such parameters as temperature, pH, and specific conductance, to determine when stagnant water had been removed from the well and "fresh" groundwater had been encountered, at which time switch to the bailer for sample collection.

Advantages:

Capable of sampling moderately deep wells.

Can be used in small diameter wells.

Portable.

Low maintenance.

Operable with a 12 volt power source.

Suitable for high-yield wells.

Disadvantages:

Low flow rates in deeper wells.

Internal components and proximity to gas fumes can negatively influence analyses.

Sample temperature may be increased.

Decontamination required.

No flow rate control.

Hi turbidity from pumping can affect analyses.

May purge low-yield wells dry.

Type available: None currently to WMA Sections.

Operation components: 12-volt battery or 12-volt source, rigid/reinforced sample line.

Attachment: Disposable filter cartridges.

PUMP OPERATION

1. Lower the pump to the desired level and secure the safety line and power line to prevent dropping the pump.
2. Connect power line to a 12-volt battery source. A fully charged battery will generally supply enough power for several wells.
3. Flow rates are not adjustable and will vary, depending on pump depth. Generally, flow rate is 1 gpm or less.
4. Use this pump only to purge high-yield wells and switch to the bailer for sample collection.

Surface Centrifugal

Surface centrifugal (impeller) pumps transport fluid by accelerating it radially outward, creating a pressure lower than atmospheric, to lift water to the surface. Specifically, a motor shaft rotates an impeller that is contained within a casing. Water that is directed into the center of the rotating impeller is picked up by the impeller vanes, accelerated by the rotation of the impeller, and discharged by centrifugal force into the casing. A collection chamber within the casing converts much of the kinetic energy to head (pressure). Certain surface centrifugal pumps are constructed for groundwater monitoring purposes. Centrifugal pump flow rates cannot be adjusted. Pump lift is limited to a maximum of 25 vertical feet. Pumping rates can reach over 10 gpm.

Advantages:

High pumping rates at shallow depths, up to 50 to 60 gpm.

Portable, self contained. No power source needed.

Low maintenance and reliable, except in silty conditions.

Suitable for purging large volumes in shallow wells.

Disadvantages:

Can de-gas volatile organic samples.

Useful only to shallow groundwater (25 ft. max.).

Pump must be primed.

No flow control.

Not generally suitable for sample collection.

Types available: Teel, Sears 2.5 hp, Sears 3.0 hp.

Operation components: Hose (various types, such as garden, large capacity/quick connect, Tygon), gas, oil, tool box.

PUMP OPERATION

1. Check oil level in pump, motor, and gas tank level.
2. Make sure engine "kill switch" is not making contact with the spark plug.
3. Attach intake and discharge line.
4. Lower intake line to a level just below the water surface.
5. Prime pump by pouring distilled water into pump impeller housing, either before attaching discharge line or directly into the discharge line.
6. Pull choke button out.
7. Pull starting cable until motor starts. Push choke to off position.
8. Covering the discharge line opening with your hand can help in creating suction.

Peristaltic Pumps

A peristaltic pump operates by suction lift. Special tubing is inserted around the pump rotor. The three-sided rotating roller surface compresses the tubing as the rollers revolve around the rotor, forcing fluid movement ahead and inducing suction behind each roller point of rotation. As the rotor revolves, water is drawn into tubing that has been lowered into the well, and is discharged by another line attached to the rotor discharge end. Peristaltic pump flow can be adjusted. The size of rotor head and the depth to water govern pump performance. The peristaltic pump can only operate to a maximum depth of 25 feet. Depending on rotor head size and depth to water, pumping rates can range from less than 1 gpm to 5 gpm.

Advantages:

Easy to operate.

Pumping rates can be fairly high, depending on size of pump head and depth to water.

Pump tubing can be changed easily.

Small pumps operate off internal or external 12-volt batteries. Larger pumps are operated using a 110-volt generator or 110 volt line.

Acceptable for collecting most inorganic samples.

Sample water contacts only the tubing, not the pump components.

Disadvantages:

Limited in use for sample collection. May alter volatile organic compounds, and some metal samples.

Limited to a maximum depth of 25 feet.

Types available: Masterflex model 7015 with 2" head (low flow rate), Masterflex model 7019 with 4" head (high flow rate).

Operation components: 12-volt battery (model 7015), 110-volt generator or 110-volt line (model 7019), flexible tubing for head, tubing for intake and discharge line, connector fittings.

Attachments: In-line disposable filter.

Note: Masterflex pumps have reverse cycling capacity.

PUMP OPERATION

1. Operation of both small and large capacity Masterflex peristaltic pumps is similar.
2. Connect pump to power source (internal power/recharge source or outside power source).
3. Lower intake line to a level just below the water surface. Secure the discharge line for disposing of water during the purge.
4. Start the pump and regulate the flow by adjusting the rheostat knob on the pump control panel.
5. Collect samples directly from pump tubing. A bailer may be used to collect samples that should not be collected from the peristaltic pump, such as volatile organic compounds. Cartridge filters may be attached to the discharge tubing.

Low-Flow Sampling

Low-flow sampling techniques are relatively recent developments in groundwater sampling methodology. The term low-flow sampling will be used here to describe these techniques. Low-flow sampling requires the use of a pump with flow control. Samples are collected based solely on field parameter stability and a stable water level, rather than on the volume purged.

Low-flow sampling is an attempt to reduce the amount of purge water removed from the well casing before sampling. Low-flow refers to the velocity the water enters the pump intake, which should be at the same rate as the natural flow of the formation water through the screened interval. Low flow purging can be accomplished using portable equipment, but it is preferable to use a dedicated system. The pump intake should be near the middle of the screen. A flow-through container or chamber should be used to monitor the field parameters for stability. Parameters are measured at intervals that will vary depending on the purge rate and the volume of the flow-through cell. Typically, a minimum of one to two liters should be purged between measurements, to clear the flow-through cell and assure fresh sample. Temperature, pH, specific conductance, and dissolved oxygen are used to determine when sampling can occur. The water level must also be monitored during purging. The water level must stabilize prior to sample collection. Wells are suitable for low flow sampling if:

1. conventional purging of 1 or more casing or borehole volumes results in purging the well dry, and
2. the water level in the well stabilizes above the well intake screen under low purge rates (100 - 500 mL/minute)

Not all wells are suitable for low-flow sampling. In low yield formations, water levels may not stabilize, and in some cases, field parameters may not stabilize. All of the requirements (stable water level, stable field parameters) need to be met for a well to be suitable for low-flow purging. Field parameters are defined as stable when three consecutive measurements do not exceed the criteria listed below (Table GWS-2).

Table GWS-2: Parameter Stability Criteria for Low-Flow Sampling

Parameter	Criteria
Water Level	± 0.20 foot for 4" diameter wells ± 1.00 foot for 2" diameter wells
Temperature	± 1 Degree Celsius
pH	± 0.1 pH units
Specific Conductance	± 5 %
Dissolved Oxygen	± 0.5 mg/l

Advantages:

Minimizes mixing between the overlaying stagnant water in the casing and water within the screened interval.

Wells purged at or below their recovery rate prevent migration of water in the formation above the well screen.

A low flow rate will reduce the possibility of stripping VOCs from the water.

Gives samples that are representative of the mobile load of contaminants (dissolved and colloidal) without pulling from the substrate.

Minimizes drawdown.

Minimizes the amount of purge water for storage or disposal.

May reduce the need for filtering by reducing total suspended solids.

Disadvantages:

In low yield formations, water levels may not stabilize.

In some cases, field parameters may not stabilize.

Flows may be so low to achieve a stable water level that filling multiple sample containers might require hours.

Drawing down the water level to below the top of the screen may affect some analytical parameters through aeration/oxidation of the sample.

The method used for low flow purging may vary, according to the individual well. The following are general protocols:

1. Measure the water level elevation. The preferable method is an electronic water level meter, with both visual and audible alarms.
2. Select a pump capable of low flow discharge rates, approximating 0.2 to 0.3 gal/min (dedicated bladder pumps are generally preferred, but submersible and peristaltic pumps may be used). Dedicated sampling equipment is preferred.
3. Locate the sampling zone at the appropriate screen level. Reference the well log for the screen zone.

Pump from the middle or upper portion of the screened interval.

4. If using portable equipment, lower the pump intake by measured cable or engineer's tape to the prescribed position. Lower the pump line slowly, to minimize disturbance of water in the casing and solids at the bottom of the well. Avoid contact with the casing wall to prevent dislodging material from the well casing wall.

5. Monitor drawdown during pumping by lowering a water level electronic sensor probe until contact with the water is made and the audible alarm sounds. The audible alarm will stop when drawdown exposes the sensor probe. If the pumping rate is set correctly, draw down should not occur during purging or sampling. If drawdown occurs during sampling, stagnant, unrepresentative water from the water column in the well casing above the screen may enter the sample zone.

6. Monitor pump discharge water for parameter stability by measuring the following: temperature, dissolved oxygen, pH, and specific conductance. Use an in-line flow-through chamber or cell for field parameter measurements. The chamber should have a small enough volume to give a rapid turnover rate. The intake should be near the bottom, and the water should flow out near the top of the chamber. The device can be as simple as a container of suitable size to contain the meter probes. Water from the pump discharge enters the container near the bottom by inserting the pump discharge tubing to the bottom of the container. One or more holes are cut into the side of the container, near the top. The container is clamped or suspended inside the lip of a five-gallon bucket, or other suitable container of known volume. The water flows up from the bottom, out through the holes near the top, and into the bucket or container.

7. When hydraulic flow of natural groundwater has been achieved, as determined by stable field parameters and water level measurements, samples can be collected.

Purging Production Wells

The Department routinely samples production wells, including domestic, industrial, municipal, and irrigation wells. These wells have pumps permanently installed, and are in use on either a continuous or intermittent basis.

Most production wells are active at the time of sampling. Domestic wells typically produce an average of 200 gallons per day. Industrial, municipal, and irrigation wells may produce much more. It can be assumed that the well is adequately purged during the day under normal conditions. Limited purging is used to clear the delivery system pipes, and to provide some cycling of water through the pressure tank (if present). If the production well is not actively in use, additional purging may be required.

A sample faucet located at the well head is ideal. If there is no faucet at the well head, or the well head cannot be accessed, then the well should be purged for a minimum of 5 minutes prior to sample collection. The temperature can be monitored during purging to assess the purge. A stable temperature is an indicator of fresh groundwater at the discharge point.

Little can be done about a holding tank in the delivery system. Running the tap long enough to cycle the well pump and exchange some of the water contained in the holding tank is recommended.

Some domestic wells may have treatment systems installed. It is important to determine the type of treatment system (if it exists) prior to sampling. Where possible, samples should be collected before any treatment system. Sometimes, outside faucets may not be included in the treatment system. For some systems, it may be possible to bypass the treatment system for purging and sampling. If it is impossible to collect an untreated sample, the use of the well for groundwater monitoring purposes may be compromised.

- A water softener will affect some common ions (e.g., chloride, calcium, magnesium, sodium, etc.). A water softener shouldn't affect nitrates, although it is preferable to collect an untreated sample.

- A carbon filter will remove organic constituents from water, but would not compromise inorganic analytes.
- Reverse osmosis will affect many analytes, but is usually only used for point treatment of a drinking water faucet (in domestic wells serving one household).

Given sufficient purging time to flush the treatment system, monitoring for parameters as temperature or pH should not be compromised.

Domestic wells are vital components in many groundwater investigations. They provide a source of groundwater quality information otherwise not available in many parts of Oregon.

When accessing a domestic system, it is important to protect the well against any contamination. If water level measurements are made, clean the measuring device thoroughly, prior to use in the well, and avoid disassembly of any part of the water system.

The following procedure is used to access, purge, and collect groundwater samples from a domestic system:

1. Obtain permission to access the water system.
2. Inspect the water system and locate the collection point closest to the well head.
3. Note the distance of the collection point to the well head. Note whether a treatment system or a pressure tank is located before the collection point. If possible, ask the owner whether the system has been used recently. It is assumed most domestic systems are in periodic use during the daytime when most groundwater sampling takes place.
4. Divert purge water away from the well head, landscaping, or any other sensitive area on the property. Prevent any damage or unsafe situation that may occur from diverted purge water.
5. Monitor temperature during purge. Temperature is the parameter used for assuring purge effectiveness of production and domestic wells.
6. After a minimum purge time of 5 minutes, the decision to collect samples is dependent on temperature stability, and knowledge of the system. It may not be possible to completely purge the system.
7. Do not try to sterilize the tap/collection point.
8. Collect water directly from the tap, after removing any appurtenances, such as a hose or a diverter. If there is restricted access to the tap, use a Teflon tube adapted for a hose bib connection to collect samples. The Teflon tube may also be connected to a 0.45-micron cartridge filter for the filtered samples. The Teflon tube should be flushed with copious amounts of well water at each sample site. A portable funnel and vacuum pump may also be used for sample filtration. A transfer container will be necessary.
9. Adjust the flow at the faucet for sample collection. Low flow (i.e., 100 mL/min.) is important in the collection of volatile organic samples.

Groundwater Sampling

Sample collection should occur immediately after the well has been purged. This will minimize sample chemistry alteration (caused by exchange of gases with the atmosphere and/or interaction with well casing material).

The rate at which a well is sampled should not exceed the rate at which it was purged. Ideally, the rate of sample collection should be approximately the same as the actual groundwater flow rate.

Sometimes, it is not possible to collect samples immediately after purging (for example, if the well is completed in a low-yield aquifer). If a well is purged to dryness, or purged such that there is insufficient volume for sampling, the well should be sampled as soon as a sufficient volume of groundwater has entered the well for a complete sample set. Samples should always be collected within 24 hours of purging. If the well has no recovery within 24 hours, it may be considered "dry". If the well has partially recovered within 24 hours, a partial sample set may be collected.

If possible, sampling should always progress from the least contaminated wells to the more contaminated wells. This is especially important when using decontaminated equipment. Samples should be collected and containerized by their volatility or chemical stability to maintain a representative sample.

Suggested sample collection order:

1. Volatile organic compounds and organic halogens (VOC, TOX).
2. Semi-volatile organic samples.
3. Dissolved & total metals.
4. Filtered inorganic samples.
5. Other inorganic samples.

Reference the DEQ Laboratory Field Sampling Reference Guide for complete preservation, sample handling, and storage information.

Sample Filtration

Some samples should be filtered in the field. Filter material should have a pore diameter of 0.45 micrometers. Filtration is generally required for samples collected for the determination of dissolved ions and dissolved metals. Filtration of a sample may cause unavoidable changes in the sample chemistry through oxidation or aeration. However, these alterations of water quality chemistry can be minimized by using consistent guidelines, such as the selection of filter type, media, pore size, etc. In-line filtering with disposable cartridge filters is recommended because it minimizes exposure of the sample water to the atmosphere and reduces sample handling.

In-Line Filtration with Pumps

1. Attach a filter to the pump discharge line. The most common filter is the disposable 0.45-µm cartridge type. Connector fittings may be necessary.
2. Reduce the pump pressure/flow rate to prevent the build up of pressure at the filter cartridge inlet. Separation of the discharge line from the cartridge can occur if pressure is too high. It may be necessary to use more than one filter if the sample has high solids content.
3. Wet the filter medium by allowing a minimum of 50 mL of water to pass through the filter cartridge prior to sample collection.

In-Line Peristaltic Pump Filtration from Bailer

1. Verify the diameter of the opening at the bailer check valve. Most are 5/8" inside diameter.
2. Cut one end of a short piece Tygon tubing at an angle. The tubing should have an outside diameter of 5/8". The angle cut is needed to push the valve ball up, allowing the sample to flow from the bailer.

3. Attach the end of the Tygon tubing that does not have the angle cut to the inlet side of the peristaltic pump head tubing.
4. Attach a 0.45-µm cartridge filter to the peristaltic pump tubing outlet end.
5. Push the Tygon tubing up into the check valve opening of the bailer until flow is achieved.
6. Start the peristaltic pump, and collected the filtered samples from the cartridge filter discharge.

In-Line Peristaltic Pump Filtration from a Container

1. Collect the sample to be filtered in a clean container of suitable volume. To reduce subsample variability, all of the filtered samples should be collected from the same container whenever possible.
2. Attach a 0.45-µm cartridge filter to the peristaltic pump tubing outlet end.
3. Place the inlet end of the peristaltic pump tubing into the container.
4. Start the peristaltic pump, and collect the filtered samples from the cartridge filter discharge.

Vacuum Type Funnel Filter

The vacuum type funnel filter is used by the WMA Sections for surface and groundwater sample filtration. Relatively clean water samples can be readily filtered with this apparatus. Refer to Appendix C of the DEQ Laboratory Field Sampling Reference Guide.

Field Parameter Test Methods

Every collected sample is tested for a certain number of routine field parameters. These parameters include temperature, pH, and specific conductance. They may also include dissolved oxygen and oxidation-reduction potential measurements (ORP or Eh). The field parameter measurement methods are each detailed in the appropriate section of MOMs.

Field parameters may be monitored in three different ways:

1. in-situ measurements in the well, using specific probes lowered to the screen
2. discrete samples collected by bailer or pump in specified containers used for field analysis
3. through an in-line, flow-through container or cell, this is used on a pump discharge line and permits continuous monitoring of the parameters.

Notes:

- Meters are available for measuring pH, temperature, dissolved oxygen, specific conductance, and oxidation-reduction potential (ORP or Eh). The Winkler titration method is preferred over probe instruments when testing for dissolved oxygen. When monitoring for parameter stability, the relative dissolved oxygen concentration is the primary concern, and a dissolved oxygen meter may be suitable.
- Typically, the first field parameter to stabilize is pH, followed by temperature, specific conductance, dissolved oxygen, and oxidation-reduction potential.
- When using the Winkler Titration Method for dissolved oxygen, the sample should be fixed immediately after collection. The sample can then be titrated anytime within 8 hours of collection. (refer to the Dissolved Oxygen Method in MOMs)

- In no case should field parameter readings be taken directly from containers that will be submitted for laboratory analysis.
- Reference the appropriate sections of MOMs for field parameter test methods.

Quality Assurance and Quality Control

For Quality Assurance and Quality Control information, reference the Quality Assurance section in MOMs.

Field Duplicate Samples

Collect a field duplicate sample for quality assurance purposes once per sampling expedition or every 10 % of samples, whichever is more. Duplicate samples should be collected as a discrete sample set, after the initial set of samples has been collected, i.e., collect the primary VOA, semi-volatile, and metals samples before collecting any of the secondary (duplicate) samples.

If field measurements of the duplicate sample do not agree with those of the "primary" sample, reanalyze the duplicate (and/or primary) sample to confirm or deny the disagreement in results. Note the re-measurement(s) on the field data sheet; do not cross out the original results.

Blank Samples

Collect appropriate blank samples once per sampling expedition. There are usually four types of blanks used for groundwater sampling. An equipment blank is the transfer of analyte-free water onsite from a transport container through the sampling equipment to sample containers. A transfer blank is the transfer of analyte-free water onsite from a transport container directly to sample containers. A transport blank is the transport of sample containers filled with analyte-free water from the laboratory to the field and back to the laboratory without opening the container. A lab-stored blank is similar to a transport blank, except the sample containers are held at the lab over the course of the sampling expedition.

Collect an equipment blank for the filtering apparatus for DM and DP/DT samples (either vacuum filtration setup or pump and cartridge filter). Filtered samples should be collected using the same method for filtering as for the groundwater samples being collected. Also, collect an equipment blank if decontaminated equipment is used. This would typically be for bailers and/or pumps. The blank water would be used to fill the bailer, or would be pumped through the pump/tubing, and into the sample containers. Equipment blanks are not collected if only dedicated, designated or new disposable sampling equipment is used.

Collect a transfer blank for the unfiltered inorganic analytes and unfiltered organic analytes. This includes the P or T polys, TM, TH, R or V, CN, Tannin/lignin, TOX, VOC, SVOC, pesticides, etc. Blank water is transferred in the field to the sample container.

Transport blanks and lab stored blanks are used for VOC samples. Transport blanks may be included for other organic analytes.

For inorganic samples, use blank water from the RO/DI tap located in the meter calibration room. For organic samples, use organic-free blank water obtained from the DEQ Laboratory Organic Section.

Refer to the DEQ Laboratory Field Sampling Reference Guide for more information. Also, see the section on Equipment Decontamination, below.

Equipment Decontamination

Decontamination is very important when using non-dedicated and non-disposable equipment. At least one equipment blank should be collected during a sampling expedition when decontaminated equipment is used.

Equipment blanks should be collected for each type of non-dedicated or non-disposable equipment used in the field. Equipment blanks should include a full set of samples.

The following methods provide effective decontamination for inorganic and organic contamination and cover the cleaning of a wide range of contaminants found in groundwater wells. Some cleaning materials can also be a source of contamination to the equipment; therefore, it is important to select cleaning materials that will be effective, without contaminating the sample. If it is known that a particular well contains a contaminant that may be used in a decontamination cleaning method, then substitute a different type of cleaner. Some common species used as decontamination cleaners are also found in groundwater wells, including acetone, hexane, and methanol.

Some cleaning agents can be detrimental to equipment integrity by reacting with equipment construction materials. It is important to use cleaning agents that will not deteriorate equipment or leave residuals. Use cleaning methods that can be verified to be effective in decontaminating equipment. Use as many equipment blanks as necessary to assure equipment cleanliness.

Method 1 (For equipment that will react with other cleaning materials)

1. Rinse with deionized distilled water.
2. Air dry or wipe with a paper towel.
3. Collect an equipment blank for analysis.

Method 2 (General use where reaction to acid or alcohol may occur)

1. Wash with non-phosphate detergent.
2. Rinse with tap water.
3. Rinse with distilled water.
4. Air dry.
5. Collect an equipment blank for analysis.

Method 3 (General use when not using metal sampling equipment)

1. Wash with non-phosphate detergent.
2. Rinse with tap water.
3. Rinse with 0.1 N hydrochloric acid.
4. Rinse with distilled water.
5. Rinse with methanol.
6. Air dry.
7. Collect an equipment blank for analysis.

Method 4 (RCRA Guidance \ Inorganic Sample Analysis)

do not use with metal (stainless) sampling equipment)

1. Wash with non-phosphate detergent.
2. Rinse with tap water.

3. Rinse with 0.1N hydrochloric acid.
4. Rinse with tap water.
5. Rinse with deionized distilled water.
6. Collect an equipment blank for analysis.

Method 5 (RCRA Guidance \ Organic Sample Analysis)

1. Wash with non-phosphate detergent.
2. Rinse with tap water.
3. Rinse with deionized distilled water.
4. Rinse with acetone.
5. Rinse with pesticide-grade hexane.
6. Air dry.
7. Collect an equipment blank for analysis.

General Approach to Equipment Decontamination in the Field and Laboratory

1. Secure an area for decontamination that is away from potential contamination sources.
2. If possible, place protective material down on the decontamination work surface.
3. Disassemble equipment when possible.
4. Clean the equipment using brushes or any other applicable materials.
5. Package equipment when possible:
    - PVC tube wrap for bailers and line.
    - PVC zip lock bags for measuring tape, filter apparatus, sample ladle, soil sample spoons, etc.
    - New plastic bags for larger items.
6. The package should be marked with the decontamination date and worker's initials.
7. Equipment unable to meet blank water checks should be taken out of service, or used for collecting samples not affected by the contaminant.

References

Bartlett, Timothy R. and & David T. Heldlauf, 1993. Effects of Monitoring Well Purge and Sampling Techniques on the Concentration of Metal Analytes in Unfiltered Groundwater Samples, Proceedings of the Seventh National Outdoor Action Conference and Exposition, May 25-27, 1993. National Ground Water Association, Westerville, OH.

Heath, Ralph C., 1983. Basic Ground-Water Hydrology, U.S. Geological Survey Water-Supply Paper 2220. U.S. Geological Survey, U.S. Department of the Interior, Washington, DC.

Oregon Department of Environmental Quality, 1997. Field Sampling Reference Guide, Version 5.0. Quality Assurance Section, Laboratory Division, Oregon DEQ, Portland, OR.

US Environmental Protection Agency, 1991a. Compendium of ERT Waste Sampling Procedures, Interim Final, EPA/540/P-91/008. Environmental Response Team, Emergency Response Division, Office of Emergency and Remedial Response, US EPA, Washington, DC.

US Environmental Protection Agency, 1991b. Handbook, Ground Water, Volume II: Methodology, EPA/625/6-90/016b. Office of Research and Development, US EPA, Washington, DC.

US Environmental Protection Agency, 1992. RCRA Ground-Water Monitoring: Draft Technical Guidance. Office of Solid Waste, US EPA, Washington, DC.

SURFACE WATER PROFILING BY BOAT

Background

Monitoring and assessing water quality conditions of large water bodies, including rivers, estuaries, bays, and offshore waters requires the use of a boat to access sampling sites and to transport equipment, samples, and personnel to and from the sites. Monitoring and assessment plans may include requirements to characterize water quality conditions over time and/or space. This is done through real-time measurements, profiling, and laboratory analysis of collected discrete water samples. Samples may be taken at multiple depths, depending on the monitoring program, assessment questions, and size and depth of the water body. For a thorough discussion on site selection and reconnaissance, see Chapter 5: Continuous Monitoring – General Considerations.

Equipment and Supplies

Staff must carefully determine the sampling objectives and requirements of any project to properly outfit a boat for sampling. For surface water measurements and sampling, the following equipment may be required:

- Water quality probes and meters – single parameter (e.g., conductivity/temperature, light) or multiparameter (e.g., YSI, Hydrolab)
- Water sampler – Van Dorn bottle, sampling bucket, bottle claw.
- Hauling system to raise and lower probes and samplers – calibrated rope and pulley, hydraulic or electric winch
- Personal Flotation Devices (PFDs) and other safety equipment
- Coolers and ice (wet and dry)
- Sample bottles and filters
- Filtration apparatus
- Sample preservatives
- Towels
- Clipboard
- Waterproof-paper datasheets and pens
- Project book
- DI rinse water
- Blank water

Calibration and Standardization

See individual sections on the various instruments for calibration and standardization procedures.

Methods

Physical measurements can be taken at various depths of the water column using a Li-Cor LI-1400 Light Meter in tandem with a multiparameter datasonde. The instrument package is lowered into the water via a rope and pulley system from the boom on the boat. Weights are added to the metal Li-Cor mounting frame and adjusted as needed to compensate for river currents. The LI-1400 Light Meter is used to measure ambient and underwater photosynthetically active radiation (PAR). The datasonde is used to measure depth, temperature, pH, dissolved oxygen, salinity, specific conductance, and turbidity. All parameters can be

measured at specific intervals depending on water column depth. For example, depths <2 m, measurements can be taken at 0.5 m from the surface and 0.5 m from the bottom. For depths >2 m but <10 m, readings can be taken at 0.5 m from surface, 1.0 m, then at 1.0 m intervals until a final depth at 0.5 from bottom. For depths >10 m, readings can be taken at 0.5 m from surface, 1.0 m, 1.0 m intervals until a depth of 10 m, then at 5.0 m intervals until a final depth 0.5 m from bottom. When using continuous monitoring equipment, allow adequate time for the reading to stabilize at each recorded depth. Data can be recorded for both the down and up cast on field datasheets, including duplicate measurements of the bottom depth.
Discrete water samples may be collected in the field for dissolved nutrients (ammonia-nitrogen, nitrate+nitrite-nitrogen, ortho-phosphate), total suspended solids, and chlorophyll *a*. A near-surface bacteria sample may be collected in the field and analyzed by the Oregon Public Health Laboratory. Water samples are collected from the side of the boat with a Van Dorn bottle sampler or bucket on a calibrated rope. Weights are added to the Van Dorn bottle handle and adjusted as needed depending on current speed. The bottle sampler or bucket is rinsed with site water prior to use. In well-mixed waters, sample bottles may be filled by the hand dip method. Temperature and specific conductance may be measured in situ.
Water samples may be taken from one to three depths at each site depending on water column depth. For depths < 1.5 m, water can be collected from a mid-depth only. For depths ≥ 1.5 but < 2.0 m, water may be collected at two depths, 0.5 m from the surface and bottom. For depths > 2 m, water may be collected from three depths, 0.5 m from the surface, 0.5 m from the bottom, and a mid-depth. For ambient monitoring, it is sufficient to collect the sample, using the sample bucket, at 1 m depth.
Once water has been collected, tilt the Van Dorn back and forth each time water is withdrawn for a sample. All discrete water sampling information will be recorded on the appropriate field data form, including and station identifier and LASAR number, sample date, time, and depth, and sample bottle numbers for each water quality test. This sheet can also serve as the chain of custody form for DEQ Labs. The item numbers on the DEQ Request for Water Analyses sheets should correspond to the item number of parameters taken for the same sample depths (i.e. Item 1, 0.5 m on profile, and 0.5 m discrete water sample bottles). Additionally, the volume of water filtered for chlorophyll *a* analyses and the corresponding depth can be recorded on the field datasheet. For QA purposes, equipment and transfer blanks and field duplicates shall be collected at 10% of the project or once per sampling expedition which ever greater.

Safety Precautions

Boom and winch system

Crew members must be alert when the boom is being operated, particularly when sampling equipment is attached. Avoid allowing the boom to swing by fixing the boom in the “out” position with the bolt when appropriate.

Boating safety

Only staff carrying the Boater Education Card may operate the boat. The following boat safety topics are included in the required education: first aid, approved fire extinguishers, personal floatation devices, flares, horns, whistles, knots, channel markers, and trailering. Crewmembers should carry knives in the event a line needs to be suddenly cut. Crewmembers should avoid riding in the bow, except to lower or weigh anchor or to scout shallow waters. Onboard electronics include mounted VHF radio tuned to channels 13 (working) and 16 (Coast Guard), cell phone, GPS, and RADAR. Crewmembers should always be alert to shifting field equipment. When sampling in the shipping lane, one crewmember must monitor ship traffic. When maneuvering the boat trailer, direct communication should be maintained between driver and spotter. See the “Working On or Near Water” JSA for further information.

References

Oregon Department of Environmental Quality, 2000. Oregon CEMAP Sampling and Analysis Plan. Western Coastal Environmental Monitoring and Assessment Program, Water Quality Monitoring Section, Laboratory Section, Oregon DEQ, Portland, OR.

SEDIMENT SAMPLING BY BOAT

Background

Monitoring and assessing the conditions of sediments in large water bodies, including rivers, estuaries, bays, and offshore waters requires the use of a boat to access sampling sites and to transport equipment, samples, and personnel to and from the sites.

Equipment and Supplies

Staff must carefully determine the sampling objectives and requirements of any project to properly outfit a boat for sampling. For sediment sampling, the following equipment may be required:

- Sediment sampling device – grab (e.g., Ekman, Van Veen)
- Hauling system to raise and lower grab – rope and pulley, hydraulic or electric winch
- Personal Flotation Devices (PFDs) and other safety equipment
- Coolers and ice
- Rulers
- Containers and spoons for compositing and transferring sediment
- Sample containers – jars, zip lock bags

Methods

Sediments can be collected using a variety of sample gear, including an Ekman or Van Veen sediment grab. Gear should be decontaminated with diluted LiquiNox soap and scrubbed prior to sample collection. Depth of penetration and various sediment descriptions (color, composition, and odor) can be recorded on the field datasheet. The sampling protocol may include specifications for acceptable samples, including depth of penetration, not canted (drastically slanted), not overflowing out the doors, not washed out, and undisturbed sediment surfaces. For safety and convenience, the sediment grab is lowered and raised using a hydraulic winch outfitted on the DEQ boat. For composite sediment samples, overlying water is drained off the sediment surface in the sediment grab or can be removed via a clean turkey baster and/or siphon with extreme care not to disturb the sediment surface. The surficial sediments are collected using a decontaminated stainless steel spoon and transferred to a decontaminated stainless steel stock pot covered with a lid and situated in ice. Composite sediments are thoroughly mixed after each grab to ensure homogeneity and contamination from outside sources (fuel, grease, sweat, etc.) must be avoided. Composite sediments are placed into appropriate sample containers for specific analyses, e.g., organics, inorganics, grain size analyses, sediment amphipod toxicity bioassay, pore water bioassays. Station identification information, sample date, time, depth, and sample container numbers are recorded on a laboratory request for analysis form. All composite samples are kept on wet ice until received at DEQ Tracking Office. For QA purposes, equipment and transfer blanks (with control sediments) and field duplicates shall be collected at 10% of the project or once per sampling expedition which ever greater.

Safety Precautions

Sediment sampler

Use extreme caution when the jaws of a sampler (Ekman or Van Veen) are cocked open. Keep hands away from the jaws when the sampler is opened. Always supervise a sampler in the hoisted position; the sampler may swing wildly when the boat rocks due to waves or crew movement.

Boom and winch system

Crew members must be alert when sampling equipment is being raised and lowered from the boom. Always secure the boom by fixing it with the bolt or bungee cord, as appropriate.
Crew must familiarize themselves with the proper maintenance and operation of the winch, hydraulic system, and gasoline engine. The exhaust cap for the engine that powers the hydraulics must be removed before starting and operating the engine. Be sure to fill the engine gas tank with clean unleaded fuel and check the engine oil level for sufficient oil. Avoid contact with both the engine and the hydraulic system, as they can become very hot.
There is a risk of capsizing when operating the winch should the grab sampler become lodged in the sediments. The boat should be secured on station with one or more anchors before lowering the grab sampler. Be sure to have bolt cutters handy to cut the winch cable in the event the sampler cannot be raised or must be abandoned because of overtaking vessels. Dangerous situations can be prevented by:

- assessing the substrate to be sampled using the onboard depth meter and appropriate charts
- posting a lookout in high traffic areas and avoiding sampling during heavy boat traffic

Boating safety

Only staff carrying the Boater Education Card may operate the boat. The following boat safety topics are included in the required education: first aid, approved fire extinguishers, personal floatation devices, flares, horns, whistles, knots, channel markers, and trailering. Boat crew should carry knives in the event a line needs to be suddenly cut. Crew members should avoid riding in the bow except to lower or weigh anchor and at times, to scout very shallow waters. Onboard electronics include mounted VHF radio tuned to channels 13 (working) and 16 (Coast Guard), cell phone, digital GPS, and RADAR. Crew members should always be alert to shifting field equipment. See the "Working On or Near Water" JSA for further information.

References

Oregon Department of Environmental Quality, 2000. Oregon CEMAP Sampling and Analysis Plan. Western Coastal Environmental Monitoring and Assessment Program, Water Quality Monitoring Section, Laboratory Section, Oregon DEQ, Portland, OR.

BENTHIC INFAUNA SAMPLING BY BOAT

Background

Monitoring and assessing benthic infauna of large water bodies, including rivers, estuaries, bays, and offshore waters may require the use of a boat to access sampling sites and to transport equipment, samples, and personnel to and from the sites. Depending on sample locations, environments, and monitoring objectives, staff will need to assess the type of equipment and methods required.

Equipment and Supplies

Staff must carefully determine the sampling objectives and requirements of any project to properly outfit a boat for sampling. The type of water body sampled will also dictate the appropriate sediment sampler and sample method. For example, lakes and backwater river sites may have finer sediments and relatively lightweight sampling equipment may be used. Sampling in river currents or in areas with harder, consolidated sediments will likely require heavier gear. The following equipment is typically required:

- Sediment sampling device – grab (e.g., Ekman, Van Veen)
- Hauling system to raise and lower grab – rope and pulley, hydraulic or electric winch
- Personal Flotation Devices (PFDs) and other safety equipment
- Rulers
- Sediment screens
- Sample containers – jars (0.5 to 1 L, seal lids with tape), zip lock bags (double bag)
- Sample transport containers – cooler, buckets with airtight lids
- Sample preservatives (e.g., ethanol or formalin, depending on the species anticipated)

Methods

See the ***Sediment*** section regarding collection of samples using a variety of sample gear, including Ekman or Van Veen sediment grabs.

Record the depth of penetration and various sediment descriptions (color, composition, and odor) for each sediment grab on the field datasheet. The sampling protocol may include specifications for the number of grabs per sample site and what constitutes an acceptable sample, including depth of penetration, not canted (drastically slanted), not overflowing out the doors, not washed out, and undisturbed sediment surfaces.

For infauna sediment samples, overlying water in the sediment grab is retained and screened with the collected sediments. All the sediments are unloaded from the grab into stainless steel mixing bowl(s) with minimal loss of water. Ambient water is pumped through a hose with adjustable flow to sieve sediments through nested 1.0 and 0.5 mm sieves (0.5 on bottom) arranged in a sediment tray. Care is taken to minimize damage to the infauna by using only gentle flows. If overflow or spill occurs during sieving, a new grab is taken for processing.

The sieved sediments are transferred with a stainless steel spoon to separately labeled (0.5 mm or 1.0 mm), double-bagged, 1 gallon heavy-duty freezer bags. A squirt bottle filled with ambient water is used to transfer the last bit of sample. Fill each sample bag about ¼ full. Avoid lying

freezer bags on abrasive surfaces due to the potential for formalin leakage. Each bagged sample has two labels recording the site information, sample number, date, depth of sample collection, sieve size, and number of bags per sample. A Rite-in-the-Rain label written on with a no. 2 pencil is placed inside the inner bag with the sample. A sticky label written on with a Rite-in-the-Rain pen or fine sharpie and covered with plastic tape is placed on the outside of the inner bag. Samples are fixed with 10% phosphate buffered formalin in a 1:2 ratio of sample to formalin. Extreme care should be used when working with formaldehyde (a suspected carcinogen and health hazard). Goggles, gloves, and respirators are encouraged when pouring formalin. Place the bagged samples into airtight 5-gallon buckets. Label buckets with site information, sampling date, and number of bags for each sieve size, as well as a DOT hazardous material sticker (Health = 3 (cancer causing), Flammability = 2, Reactivity = 2, contact = 3 (corrosive)). The sample information must be recorded onto the *DEQ Request for Sediment Analyses* form, which serves as the chain of custody form and should accompany sample buckets until they are received at the laboratory. Within 14 days of collection, re-screen benthic infaunal samples and transfer them into alcohol (70% ethanol) for long-term storage and handling. Ethanol-preserved samples can then be shipped to contractors for sorting and identification.

Safety Precautions

Sediment sampler

Use extreme caution when the jaws of a sampler (Ekman or Van Veen) are cocked open. Keep hands away from the jaws when the sampler is opened. Always supervise a sampler in the hoisted position; the sampler may swing wildly when the boat rocks due to waves or crew movement.

Boom and winch system

Crewmembers must be alert when sampling equipment is being raised and lowered from the boom. Always secure the boom by fixing it with the bolt or bungee cord, as appropriate.

Formalin and ethanol handling

Both formalin and denatured ethanol present health hazards due to exposure and flammability. Routes of exposure are inhalation, ingestion, and absorption. Handle these chemicals with goggles and PVC gloves. Protect your skin and clothes with plastic aprons. Handle these chemicals with adequate ventilation, whether in open air on the tail of the boat, or in a ventilated hood in the lab. If these options are unavailable, use respirators. Extinguish all flame sources, including cigarettes, when handling these flammable chemicals. See the "Infauna Field Collection and Re-Screening" JSA for more information.

Boating safety

Only staff carrying the Boater Education Card may operate the boat. The following boat safety topics are included in the required education: first aid, approved fire extinguishers, personal floatation devices, flares, horns, whistles, knots, channel markers, and trailering. Boat crew should carry knives in the event a line needs to be suddenly cut. Crewmembers should avoid riding in the bow except to lower or weigh anchor and at times, to scout very shallow waters. Onboard electronics include mounted VHF radio tuned to channels 13 (working) and 16 (Coast Guard), cell phone, digital GPS, and RADAR. Crewmembers should always be alert to shifting field equipment. See the "Working On or Near Water" JSA for further information.

References

Oregon Department of Environmental Quality, 2000. Oregon CEMAP Sampling and Analysis Plan. Western Coastal Environmental Monitoring and Assessment Program, Water Quality Monitoring Section, Laboratory Section, Oregon DEQ, Portland, OR.

FISH SAMPLING BY TRAWL LINE

Background

Monitoring and assessing the conditions of large water bodies, including rivers, estuaries, bays, and offshore waters requires the use of a boat to access sampling sites and to transport equipment, samples, and personnel to and from the sites. When assessing the biological integrity of a water body, data on fish community structure and fish tissue analyses provide valuable information.

Community structure information is gathered using trawling methods. Depending on the assessment questions and site conditions, trawls can vary in mesh size, mouth opening, and trawling depth. Trawling method variables include time length and/or distance of trawl, location of trawl, direction of trawl relative to the sample site and/or any existing currents. Collection of fish can be by trawl or hook and line.

Equipment and Supplies

Staff must carefully determine the sampling objectives and requirements of any project to properly outfit a boat for sampling. For fish community and tissue sampling, the following equipment may be required:

- Trawl nets
- Gloves
- Personal Flotation Devices (PFDs) and other safety equipment
- Live well – basin or bucket
- Day shapes – to alert other vessels that trawling gear is overboard
- Coolers and ice
- Rulers
- Preservatives – for pathology samples

Methods

Trawl Fish Sampling (Standard CEMAP Method)

A 16’ bottom otter trawl is used to perform 10 (+/- 2) minute trawl(s) to characterize the fish community and collect whole fish tissue for chemical analyses. Appropriate rope lengths are between three to six times the depth for the trawl line (excluding the bridal), and one and a half times the depth for tag float line. Trawl deployment and retrieval from the vessel require left hand circles (chasing the tag float) and close coordination between the crew to avoid tangling the net in the propeller. The ideal trawling track is a straight line centered over the station (begin ~ 0.2 mile from site) at approximately 3-4 knots speed over ground (SOG). Trawl information including coordinates, time, length of rope/wire, average SOG, trawl debris, and use of trawl catch (assemblage, chemistry, pathology) will be recorded onto the *Trawl Event Information* field datasheet.

A 10 (+/- 2) minute trawl can be used to characterize the fish community. The trawl catch is immediately transferred into a live well and examined for fish, invertebrates, vegetation and debris. All fish and invertebrates are examined for external anomalies. Salmonids are identified and measured first then immediately released alive to avoid incident mortality.

NOTE: ANY TAKE OF LISTED SPECIES MUST BE REPORTED IMMEDIATELY TO THE APPROPRIATE STATE AND FEDERAL AGENCIES. TAKE PERMIT PROVISIONS MAY REQUIRE ALL SAMPLING TO CEASE IN THE EVENT OF INCIDENTAL TAKE.

Up to 30 individuals of each fish species are measured for size class after which an estimate can be made. Fish species names, size class (forklengths, total length if non-forked), frequency, and noted anomalies (i.e. fin rot) are recorded onto the *Trawl Fish Abundance* field datasheet. Invertebrate upper phylogenetic (i.e. family) or common names, frequency, and external anomalies (i.e. parasites) will be recorded onto the *Trawl Invertebrate Abundance* field datasheet. The approximate presence and abundance of exotic species, vegetation (submerged aquatic grasses and macroalgae for this project), and trash will be recorded onto the *Trawl Event Information* datasheet.

Gross External Fish Pathology

Any fish pathologies (i.e. tumors) are photographed, then excised and placed into an orange labeled pathology cartridge, and put immediately into Dietrich's solution. Excised tissue must include the entire pathology and some adjacent healthy tissue. Pathology information including cartridge number, fish species, size, station information, trawl number, pathology location, description, and sample depth will be recorded onto the *Cumulative Fish Pathology Log*. Up to 60 cartridges can be placed in a 2 L Dietrich's Container. The pathology log can serve as the chain of custody form for collected samples.

Chemistry Fish Tissue Samples

Some trawl fish catch can serve as target species for chemical analyses of inorganic and organic contaminants. Fish tissue drying, grinding, and analyses are performed at the DEQ lab. Depending on the monitoring plan, ideal target species could include demersal fishes that are also in higher trophic levels of aquatic food webs. Demersal fish are bottom foraging fish that normally live near or on the seabed. Estuarine target fish species include sandabs (Pacific and Speckled), sole (English), flounder (Starry), and sculpin (Pacific Staghorn and Prickly). Freshwater target species include white sturgeon, carp, catfish, northern pike minnow, peamouths, chisel-mouthed chubs, and bass. In the event no target species are caught in the trawls, abundant demersal or mid-water fishes can be used as surrogate target species.

Ideally, 5 to 10 individuals of a target species will be retained from each site for chemical analysis. A minimum of 50 g wet-weight is needed for a single-species fish chemistry sample, and 200 to 300 g wet-weight is ideal. Two target species may be taken from each site. A second 10 (+/- 2) minute trawl is encouraged if additional chemistry fish might be caught to fulfill the targeted fish mass. No characterization of invertebrates, non-target fish species, or debris is necessary for the second trawl effort. Hook and line may be used as an alternative means to collect target fish species for chemical analyses. Record the number of trawls and collection method used to fulfill the targeted fish mass for chemistry samples.

Care must be taken to ensure fish for tissue analysis are not contaminated by foreign materials. Do not allow fish to fall to the floor of the boat. Place individual fish in appropriately-sized containers or wrap whole in aluminum foil. Metals contamination from the foil is minimized by using whole fish, rather than fillets. In addition, the fish are rinsed with DI water prior to them being homogenized.

Affix a Rite-in-the-Rain label written on with pencil. The label should not touch the fish. The label will specify the site information, corresponding sample identification, sample date, species common name and code (the first four letters of genus and species names), and the number *i* (where $i = 1, 2, 3, \ldots, n$) of the individual fish of the total number *n* of fish collected for that species. Individually wrapped fish of the same target species will be combined into 1 gallon freezer bag(s) or plastic garbage bags with a taped-over sticky label containing the same information as the inner label, except with the bag number of the total number of bags.

Chemistry fish samples remain on dry ice until received at DEQ lab. Fish sample information, target species, and the number of fish per the number of bags are recorded on the *Trawl Fish Abundance* field datasheet. Fish sample information, target species, site description and name, sampling time and depth, and trawl number are recorded on the *DEQ Request for Fish Tissue Analyses* chain of custody form.

For QA purposes, fish voucher specimens are collected periodically for verification. Fish voucher specimens are individual fish collected in the field and brought back to the lab for positive identification. This ensures the field crews are correctly identifying species.

Safety Precautions

Trawl equipment

Crewmembers must be vigilant of all trawl equipment and lines to avoid being tangled in the equipment. Nets, bridles, lines, and doors must be deployed, retrieved, and stored in an organized and clean manner to avoid fouling.

Boating safety

Only staff carrying the Boater Education Card may operate the boat. The following boat safety topics are included in the required education: first aid, approved fire extinguishers, personal floatation devices, flares, horns, whistles, knots, channel markers, and trailering. Boat crew should carry knives in the event a line needs to be suddenly cut. Crew members should avoid riding in the bow except to lower or weigh anchor and at times, to scout very shallow waters. Onboard electronics include mounted VHF radio tuned to channels 13 (working) and 16 (Coast Guard), cell phone, digital GPS, and RADAR. Crew members should always be alert to shifting field equipment. See the "Working On or Near Water" JSA for further information.

Reference

Oregon Department of Environmental Quality, 2000. Oregon CEMAP Sampling and Analysis Plan. Western Coastal Environmental Monitoring and Assessment Program, Water Quality Monitoring Section, Laboratory Section, Oregon DEQ, Portland, OR.

BENTHIC MACROINVERTEBTRATE PROTOCOL FOR WADEABLE RIVERS AND STREAMS

Background

Evaluating the biological community of a stream through an assessment of the macroinvertebrates provides a sensitive and cost effective means of determining stream condition. The goal of the protocol described in this section is to collect an unbiased, representative sample of benthic macroinvertebrates in wadeable streams and rivers. At each stream reach, samples are collected by compositing D-Frame Net kick samples from a selected habitat unit (e.g. pools, riffles).

Samples are preserved in the field with ethanol. Subsampling the composite sample is necessary since the composite usually contains far more material and macroinvertebrates than is desirable to process and identify. Subsampling and identification is performed either by DEQ laboratory personnel or by qualified contractors.

This protocol covers field sample collection methods, sample tracking and record keeping, subsampling, macroinvertebrate identification, quality assurance, and safety. It does not cover data analysis and interpretation.

Two variants of the field collection protocol used by DEQ are described here. One is targeted habitat sampling, which is the standard DEQ protocol, and the other is transect sampling, a protocol presently used only for EPA-funded studies such as the Environmental Monitoring and Assessment Program (EMAP) (Peck, et. al., 2000).

Field Collection Methods

Equipment and Supplies

- 500 um mesh D-Frame kick net
- Three gallon sieve bucket
- Scrub brush
- Long-sleeved rubber gloves
- Zip-loc bags or Nalgene containers
- Sample label
- Waders with slip-resistant soles

Overview of the differences between the two collection methods:

Standard Oregon DEQ

- 8 kick composite (each kick 1 foot by 1 foot)
  ---prior to 2003, DEQ collected four 2-foot^2 kicks
- 9 cell grid overlay to select sites
- collect riffles at all sites (if no riffle collect a pool sample)
- collect riffles and pools at reference sites only

EMAP

- 8 kick composite (each kick 1 foot by 1 foot)
- 9 cell grid overlay to select sites
- Collect riffles and transect samples at all sites
- Collect pool samples only if riffle habitat is unavailable

Targeted habitat sampling

1. Beginning at the downstream end of the reach, select the first riffle or pool habitat unit (riffles at all sites, pools only if reference site or no riffles present). Collect one kick sample from each riffle or pool unless fewer than eight are present within a reach. In that case evenly spread the eight samples across the number of riffles or pools within the reach, excluding margin habitats (area within 5% of channel margins).

   Visualize a 3 ft by 3 ft grid over each riffle (or habitat unit) to be sampled (**see Figure 3**). For the first habitat unit, select the lower-left square; for the second habitat unit, select the lower-center; the third, the lower-right; for the fourth, select the middle-left; for the fifth select the middle-center; for the sixth select the middle-right; for the seventh select the upper-left; for the eighth select the upper-center. Collect the kick sample in the center of each grid square.

Figure 3 **Visualize a grid overlay to select kick sites at each habitat unit (riffle or pool).**

7	8	
4	5	6
1	2	3

2. After locating the random sample location, place the net into the stream with the flat part of the hoop resting on the bottom and perpendicular to the stream flow. As much as possible, make sure to remove any substrate that prevents the flat part of the kicknet from sitting flush with the bottom. It may also be useful to remove large substrate particles downstream of the flat portion of the loop that may affect the flow entering the net. Collect the macroinvertebrate sample by disturbing a 1 ft by 1 ft area.

3. Inspect the benthos in a 1 ft by 1ft area (approximately as wide as the kick net) of stream bottom directly in front of the net for any large organisms such as mussels. Pick these and place in the sieve bucket.

4. Carefully rub by hand all substrate larger than five centimeters (golf ball size and larger) in front of the net to dislodge any clinging macroinvertebrates. Then, with a small scrub brush dislodge organisms still clinging to the larger substrate particles. After rubbing, place the substrate outside of the sample plot. (Hand scrubbing is recommended prior to using the brush to prevent damage to fragile macroinvertebrate specimens. Also, be gentle with the brush, so as not to harm the macroinvertebrates.)

5. Thoroughly disturb the remaining substrate in the 1ft by 1ft area with your hands or feet for 1 min to a depth of five to ten centimeters.

- **NOTE:** Collecting a sample in slow moving water is a little more difficult. It may involve pulling the net through the water as the substrate is disturbed to capture suspended organisms.

6. After the sample is collected and the net removed, return the large substrate to the sample plot.
7. The contents of the net are placed in a sieve bucket and the sampling procedure is repeated for that habitat type. Always sample downstream to upstream.
8. All kick samples for the same habitat type are composited in the sieve bucket. Large organic material and rocks are rinsed, carefully inspected for clinging macroinvertebrates, and removed. As much fine sediment as possible should be washed away. Leaf packs from pool samples may require considerable rinsing and removal of debris before preserving the composite sample.
9. The composite sample is placed in a labeled jar or double zip-lock bag and preserved with 95% denatured ethanol for sorting and subsampling in the lab. Pour enough Ethanol in the container to equal the volume of sample. It is necessary to replace the alcohol in the sample with fresh alcohol within one week to ensure adequate preservation. Typically, each sample should have its ethanol changed at the end of each field week, unless the ethanol is still clear (not green or brown). Place a label (Rite in the Rain paper) written in pencil containing site and habitat unit information inside the container. Label the outside container with a pencil written on a label, and then tape the label to the outside of the jar. Do not use markers as most inks are soluble in alcohol.
10. After samples are collected in the field, several steps should be taken before they can be put away. We recommend changing the alcohol preservative within a few days of collection. This is especially important if the sample contains a lot of wet organic material (leaves, moss, etc.) that would dilute the alcohol. Containers should be checked for leaks and complete labeling. Samples need to be stored in a neat and systematic manner. Samples are also entered into a sample tracking system, described in the following section.

Transect sampling (EMAP only)

Select the transect A sample location at the middle of the left one-third of the stream. For transect B set the net in the middle of the center one-third of the stream. For transect C, set the net at the middle of the right one-third. For transect D, start back at the left one-third. Repeat the cycle for all 11 transects. (Be sure to follow the L, C, R, L, C, R pattern. DO NOT oversample the middle section.) EXCLUDE the margins (see Peck et al 2000, for further details).

Use the sampling and processing techniques described above.

Sample Tracking and Record Keeping Method

1. In order to adequately track each invertebrate sample, the following parameters are needed: Station (the number DEQ uses to represent a unique sampling location), site name, site ID (depending on project), collection date, habitat sampled, sample collection QA code (S = Sample, FP = Field Primary, FD = Field Duplicate), the number of jars used for the entire sample, and the collector's initials. Each of these parameters should be verified against the "Sample Tracking" form, which is turned into the Sample Tracker's office for entry into the Laboratory Information Management System (LIMS).

2. Tags with all the information listed above should be placed inside the container and also attached to the outside (staple or tape). Be sure to use a pencil, not a marker.

3. Samples with "clean" ethanol should be placed in the Bio Lab on the benches identified for bug storage. Be sure to place the samples in the appropriate area designated by project.

4. At periodic intervals throughout the field season, staff will move the accumulated bug samples to the designated area in the Water Monitoring and Assessment lab area until they are shipped. For all projects other than EMAP, use the blue or green Tupperware bins. Label the outside of the bin with the project name and a unique bin number. For EMAP samples going to EPA in Corvallis, use the white screw-top buckets. Each screw-top bucket should have a unique number (if it does not, assign one).

5. Record the bin/bucket number that each sample is placed into on a hard copy of the "Sample Shipping" form. When a bin/bucket is full, make a photocopy of the shipping form for our records, and place the original inside the bin/bucket. (Be sure to note jar numbers. For example, if a sample has 6 jars, you may need to place "jars 1-3 of 6" in bin # 3, and "jars 4-6 of 6" in bin # 12.)

Subsampling Method

Subsampling is a cost effective way to reduce the time and effort required for sample processing. It involves sorting only a portion of the sample collected. On average, expect to spend at least 3 hours sorting a sample. Subsampling takes patience and cannot be rushed.

Equipment and Supplies

- 500 um metal sieve
- three gallon sieve bucket
- 30 cm X 36 cm metal mesh tray with rectangular plastic pan (for a description of the Caton Subsampling Tray see: Caton, 1991)
- Random Sub-sampling Tool: a cookie-cutter-like metal box (6 cm x 6 cm x 6cm) with no bottom or top. When placed in the sorting tray at randomly selected locations it defines a portion of the sample to be removed for sorting.
- 6 cm metal flat scoop
- paintbrush
- forceps
- Petri dish
- glass specimen vials with caps
- sample labels (Rite in the Rain paper)
- counter
- 75% Ethanol for macroinvertebrate preservation
- dissecting microscope with light source

Procedure

1. Select a sample for subsampling and sorting. Drain the Ethanol from the sample under the fume hood. Rinse out as much fine sediment, big, rocks, etc., as practical. The metal sieves and sieve bucket are useful for this as well as the screen for the Caton Subsampling tray.

Some samples are in more than one bag and should be composited and completely mixed in the sieve bucket.

2. Place the mixed composite sample in the 30 cm by 36 cm metal mesh tray (Caton subsampling tray). If the composite is too large to reasonably fit into the tray, divide the sample in half one or more times until a workable amount of material is obtained. Make a note of any composite divisions. Put the screen tray inside the white plastic tray and add enough water to float and completely mix the sample. This ensures a random and even distribution of the debris in the tray. Lift the screened tray out of the water.

3. The sorting tray is 36 cm long by 30 cm wide, which equals six sub-sampling tool widths along the length of the tray and five along the width of the tray. Use a random number table to determine where the random sub-sampling tool should be placed in the tray (much as coordinates for a graph). The first number from the table is used to determine the position of the sub-sampling tool along the length of the tray. The second random number is used to determine the position along the width of the tray. Based on the random numbers, place the sub-sampling tool at the appropriate location within the sorting tray and remove the delineated sample material. Sticks, leaves and other debris that overlie the grid should be cut with scissors or a razor blade. Use the 6 cm flat metal scoop and brush to remove the debris and invertebrates from the square and place in a separate container.

4. Place approximately one or two cubic centimeters of material in a small, shallow dish (such as a Petri dish) with a small amount of water. Pick out all the invertebrates using forceps and a dissecting microscope and 10X magnification with a light source. Count the macroinvertebrates as you remove them (counters are extremely useful). Place them in a glass vial with 75% Ethanol. Sort the entire subsample thoroughly.

5. Continue selecting and sorting sample squares until a minimum of 500 macroinvertebrates have been sorted. If you are part way through a subsampled square and you reach 500 invertebrates you must pick all the invertebrates remaining in the square. The maximum number of squares to pick is 16. Do not exceed 16 squares, even if 500 macroinvertebrates have not been reached.

6. Pick every invertebrate you can see. BE CAREFUL! There are many invertebrates that can be easily overlooked. Among the most commonly missed are invertebrates that are in some type of case. Caddisflies can be found in cases made of stone, sand, leaves and twigs. When caddis pupate they often close off their case, so a case that is blocked at one end may still contain a caddis. Some species of Chironimidae and Oligochaeta can be found in cases made of fine sediment and sand. Another frequently missed organism is *Cricotopus nostocladius* - a chironomid often found encased in an algal sheath. Also, watch for plant material that may resemble an organism. Check each mollusk shell for an organism. If you are unsure about whether or not something is actually an organism, the best thing to do is put it in the vial, but do not count it.

7. Retain the sorted debris for an independent check of sorting efficiency. The aim is to remove all macroinvertebrates though, in practice, this is not always achieved (better than 95% removal should be achieved at all times). Novices should have the debris from every sample checked by an experienced bug picker until better than 95% efficiency is achieved. Experienced bug pickers should have ten percent of picked samples checked by a second person before discarding sorted material. If greater than 5% of the total is found the original sorter must continue to pick and the sample must be checked again. After the sample is checked again and less than 5% invertebrates are found the remaining debris can be discarded.

8. When you are finished, label the vial with the site name, sample date, habitat type, sample collection QA code (from sample container tag), number of squares sorted, the number of invertebrates (either "500+" or the actual number if below 500 organisms), and subsample processing QA code (S = Sample, CP = Contractor Primary, CD = Contractor Duplicate). Also place a paper label on the inside (written in pencil on Rite in the Rain paper) with the same information. Place the vial on the appropriate shelf and record your name, date, number of invertebrates, and squares picked. Also record this information in the bug logbook. Mark in the 'sorted' column of the bug logbook that the sample has been picked (your initials, date, number of squares, and number of insects).

Macroinvertebrate Identification Method

Equipment

- dissecting microscope (10X-60X zoom)
- light source
- forceps
- macroinvertebrate taxonomic keys. See references for recommended keys
- data recording form

Procedure

1. A consistent and sufficient level of macroinvertebrate taxonomy of reliable quality is critical. **Table 2** lists the level of taxonomic identification for different macroinvertebrate taxa used by DEQ.
2. Experienced entomologists using current taxonomic keys (see "Taxonomic References") under the supervision of a senior aquatic entomologist should perform identification to genus/species. Family level identification is possible by less experienced staff, but sufficient taxonomic training is still critical. Identification of animals to a coarser family taxonomic level may limit data analysis and interpretation.
3. The number of each taxon is noted on a tally sheet along with other site identifier information.
4. Quality control procedures described in the Quality Assurance section should be completed to evaluate and document the quality of the sample identification.

Table 2 Level of identification for aquatic macroinvertebrate orders used by DEQ

EPHEMEROPTERA - genus level except as noted below:
- Baetidae - genus only except for *Baetis tricaudatus or bicaudatus*
- Ephemerellidae - species in almost all cases
- Heptageniidae - genus only except for *Epeorus* (*albertae, longimanous, grandis*, etc.)
- Leptophlebiidae – genus except for *Paraleptophlebia bicornuta*

PLECOPTERA - genus level except as noted below:
- Capniidae - family only
- Chloroperlidae – genus in late instars
- Leuctridae - genus
- Nemouridae - genus except species for *Zapada* (*cinctipes, frigida* etc.)
- Peltoperlidae - genus
- Perlidae - species
- Perlodidae - genus
- Pteronarcidae – genus except for *Pteronarcys californica*
- Taeniopterygidae- genus

TRICHOPTERA - genus level except as noted below:
- *Rhyacophila*- to group except:
  - Betteni gr. - *R. malkini*
  - Lieftinchi gr. - *R. arnaudi*
- Sibirica gr. - *R. blarina* and *R. narvae*

COLEOPTERA - Generally keep everything at family level except for genus level for Psephenidae, Hydrophilidae, Haliplidae, and Elmidae.

DIPTERA - genus level for all families except for:
- Chironomidae - sub family.
- Ceratopogonidae - sub family.
- Tabanidae, Dolichopodidae, Ephydridae, Sciomyzidae, Syrphidae - family level only.

GASTROPODA - genus level where possible (generally not possible for Physidae).

HEMIPTERA - genus level apart from Corixidae (family only). (In many cases we should not be counting marginally aquatic Hemipterans such as Gerridae.

ODONATA - genus level.

CRUSTACEANS - usually genus level.

PELECYPODA - family level only.

LEPIDOPTERA/MEGALOPTERA - genus level.

Quality Assurance

Overview

Quality assurance procedures (QA) assess the environmental variability, sampling procedure validity, repeatability of the sample methods, and identification quality. The quality assurance procedures involve a system of standard methods and protocols, duplicate sampling, and identification reviews.

Field Sample Collection QA

Ten percent of all stream sites sampled, or one sample per survey, whichever is greater, should have a duplicate set of field samples collected. The duplicate sample is from the same sample reach.
Field QA samples look at the natural variability within a riffle and insure that the field sampling method is repeatable. This sample is sorted and identified the same as any other sample.

Subsampling QA

1. Retain the sorted debris from the subsample for an independent check of sorting efficiency. The aim is to remove all macroinvertebrates though, in practice, this is not always achieved (better than 95% removal should be achieved at all times). Novices should have the debris from every subsample checked by an experienced bug picker until better than 95% efficiency is consistently achieved. Experienced bug pickers should have ten percent of picked samples randomly selected for checking by a second person before discarding sorted material. If greater than 5% of the total is found the original sorter must continue to pick and the sample must be checked again. After the sample is checked again and less than 5% invertebrates are found, the remaining debris can be discarded.

2. Ten percent of all composite samples collected, or one sample per survey, whichever is greater, is resorted for an additional 500 specimen subsample from the original preserved composite sample. The result is a duplicate sample from the same composite. Lab QA samples look at the variability inherent in the subsampling procedure and insure that the subsampling method is repeatable and within an acceptable range of variability.

Type collection

It is useful to maintain a macroinvertebrate type collection for each major basin, watershed, project, or ecoregion studied. This collection has a representative of each taxon identified and serves as a basin record, and as a reference for checking identifications.

Identification review

An experienced taxonomist who did not originally identify the samples should review the identification data for anomalous identifications. Randomly selected samples should also be re-identified by an experienced entomologist independently of the first identification. Finally, an experienced entomologist should periodically check the identification accuracy of specimens entered into the type collection.

Safety

It is difficult to provide detailed safety procedures for macroinvertebrate sample collection and processing due to the wide variety of circumstances that could be encountered in collecting and processing macroinvertebrate samples. The items listed below serve as a general guide.

- Field crew members should stay within shouting distance, if not visual contact, at all times.
- Field crew members should be familiar with how to minimize their risk of attack by cougars and bears.
- Field crews should use caution when collecting samples and walking in deep streams, fast moving water, or when walking on slippery or loose surfaces. If the randomly selected sample location is unsafe to sample but a similar spot nearby can be sampled safely then the safe spot should be sampled. The macroinvertebrate sampler should ask other field crew members for assistance in collecting the sample, if needed. See the "Working On or Near Water" JSA for further information.
- Use adequate ventilation when using denatured ethanol. Avoid prolonged contact with skin. Transport ethanol containers inside a cooler or other container with a tight fitting lid to contain leaks and fumes.
- Ethanol is flammable. Avoid exposure to flames and extreme heat.
- Denatured ethanol contains several percent of toxic chemicals. It cannot be safely diluted to make alcoholic beverages.

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AQUATIC VERTEBRATE SAMPLING IN WADEABLE STREAMS USING BACKPACK ELECTROFISHING

Background

This protocol is from the EPA stream monitoring manuals used by DEQ for the past several years (Peck et al. 2000, Hayslip et al. 1994), as well as the National Marine Fisheries Service Backpack Electrofishing Guidelines of June 2000. It describes using a backpack electrofisher in wadeable streams to determine the aquatic vertebrate species (plus crayfish) present, relative species abundance, length, and the presence of external anomalies. The objective is to collect a representative sample of all but the rarest species present. It is a qualitative, single pass, survey conducted by a crew of at least three people in a reach of wadeable stream. The length of stream surveyed is 40 times the wet width of the stream, usually a few hundred meters. The time to complete the survey is usually three to five hours.
Electrofishing is conducted with permits issued by the Oregon Department of Fish and Wildlife, National Marine Fisheries Service, and the US Fish and Wildlife Service. Field crews must carry copies of the permits and follow any special conditions of the permit.
The battery powered backpack electrofishers used by the DEQ Water Monitoring and Assessment (WMA) Sections are made by Smith-Root, Inc. (14014 NE Salmon Creek Avenue, Vancouver, WA 98686; (360) 573-0202).

This protocol covers field operations, laboratory voucher verification procedures, data verification, quality assurance, and safety. It does not include species identification, data analysis and interpretation, or the principles of electrofishing theory. See Allen-Gil (2000) for an electrofishing theory discussion.

Field Equipment

- Smith-Root Model 12 or 12B backpack electrofisher
- Six foot pole anode with 11 inch ring cover and netting
- Two charged electrofisher batteries
- Two dip nets
- Two small aquarium nets
- Three dark colored 3 gallon plastic buckets
- Fish measuring board
- Data recording forms, “rite in the Rain” paper preferred
- Clipboard
- Pencils
- Fish identification keys (see references)
- Small nylon mesh bags or stockings for vouchers (a specimen retained for verification of the "in-field" species identification back at the lab)
- Zip-lock or Whirl-pack bags for vouchers
- Voucher labels, “Write in the Rain” paper preferred
- Voucher jar
- Ethanol (or formalin) for preserving vouchers
- Fish anesthesia (MS 222)
- Waders with felt soles
- Heavy rubber electrician’s gloves
- Thin rubber gloves
- Conductivity meter
- Backpack
- Polarized sunglasses
- Hat with brim or visor

Field Methods

1 During a typical stream survey, the vertebrate portion is conducted in the afternoon after the chemistry, macroinvertebrate, and habitat portions of the survey have been completed. The crew takes a brief break at the downstream end of the reach to let the stream 'settle'.

2 The goal is to representatively survey the vertebrate assemblage of the entire reach as part of a comprehensive stream assessment completed within the time constraints of a single day. If necessary, allocate the electrofishing effort proportionally among transect intervals. The stream survey reach is 40 times the wet channel width. This reach is divided into ten segments by eleven transects (this is done in the morning during the habitat portion of the survey). Allocate approximately one-tenth of the electrofishing effort to each interval, realizing that more complex habitat or areas with more fish will take longer to survey. EPA protocols specify that the time spent actually electrofishing ("button time") should not exceed 5000 seconds (Hayslip et. al 1994) and the total electrofishing survey should not take less than 45 minutes nor more than three hours (Peck et al. 2000). In practice, DEQ field crews have found that the 5000-second limit is seldom reached, while the 3-hour limit is often not enough time. The number of daylight hours remaining may be a factor in how much time is allowed for electrofishing. If there is insufficient time, the crew should plan to return another day to complete the survey.

3 Select the electrofisher settings based on the conductivity of the water. To minimize aquatic vertebrate stress and mortality, it is very important to use the minimum amount of electrical energy to stun fish and amphibians. Increasing the voltage, pulse width, and pulse frequency increases the fish collection effectiveness; however, stress and mortality is also increased. **Table 3** contains maximum settings for waters containing Endangered Species Act (ESA) listed species. **Table 4** is a summary of **Table 3** and is attached to the electrofisher. Start with settings below those specified and incrementally increase up to the specified limit if necessary to collect fish. Record electrofishing start time and electrofisher settings in the electrofishing log portion of the field form.

Table 3 Guidelines for initial and maximum settings for backpack electrofishing.(NMFS2000)

	Initial settings	Maximum settings	Notes
Voltage	100 V	Conductivity (μmhos/cm) Max. Voltage < 100 1100 V 100 – 300 800 V > 300 400 V	*In California coastal basins, settings should never exceed 400 volts. Also, no electrofishing should occur in these basins if conductivity is greater than* 350 μmhos/cm.
Pulse width	500 μsec	5 msec	
Pulse rate	30 Hz	70 Hz	*In general*, exceeding 40 Hz will injure more fish.

Table 4 Electrofisher Settings label on DEQ electrofishers

Electrofisher Settings Jun 99

Voltage

Ambient Conductivity (µmhos/cm)	Voltage (V)
Less than 100	900 to 1100
100 to 300	500 to 800
Greater than 300	150 to 400

Pulse Width

Start with minimum pulse width and increase as needed to capture fish. Start with pulse width of 500 microseconds, do not exceed 5 milliseconds.
See Smith-Root Model 12B POW settings F1 to F4, and G1 to G4.
Not adjustable on Smith- Root Model 12.

Frequency

Start at 30 Hz. Generally should not exceed 40 Hz.

Temperature

ESA listed fish must not be handled if water temperature exceeds 70 F (21 C).

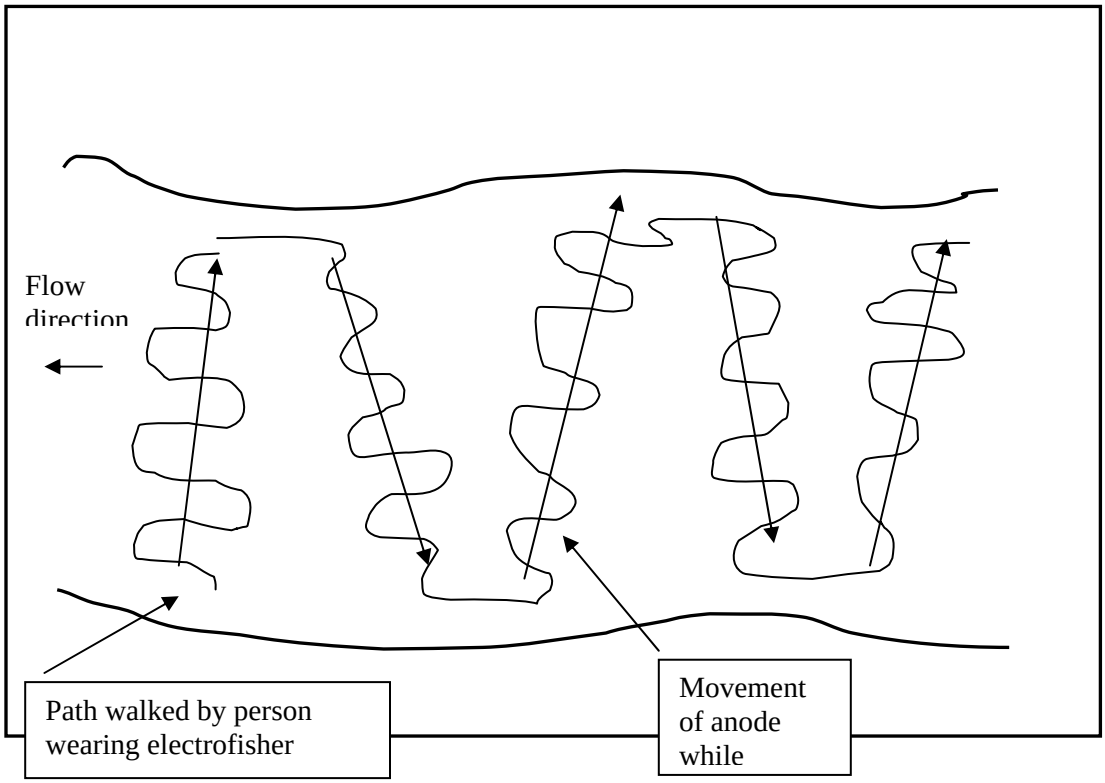
4 Do not electrofish in waters with ESA listed species when the water temperature is ≥18^{o} C, or is expected to rise above 18^{o} C before completing the electrofishing survey.

5 Crewmembers should wear polarized sunglasses to help see fish in the water, if necessary.

6 Reset the electrofisher timer to zero.

7 Beginning at the downstream end of the reach, fish in an upstream direction. Depress the anode thumb switch and slowly sweep the anode side to side through the water. **Figure 4** shows a typical electrofishing pattern.

Figure 4 Typical Electrofishing Pattern



8 The crewmembers with dip nets (the netters) should hold their nets downstream from the anode, net stunned animals, and place them in a bucket of stream water. In slow moving water, the nets will be one to two feet from the anode. In faster current the nets may be a little further away from the anode.

9 The netters should always be downstream of the electrofisher.

10 Netters should not allow stunned fish to remain in the electric field longer than necessary. Remove fish from the water as soon as they are stunned.

11 Sample all habitats in approximate proportion to their presence in the reach, including undercut banks and large woody debris. To sample undercut banks move the anode into the habitat with the electrode on and then remove the electrode quickly to pull stunned fish out of hiding.

12 Use extra caution electrofishing areas like undercut banks where fish may be concentrated and visibility poor. Do not fish such areas for an extended period. Keep the electrode moving.

13 Keep anode and cathode closer together (but not touching) in low conductivity water or if catch efficiency seems low.

14 Although most captures will be around the anode, the netters should keep track of the area around the cathode as well. The cathode also stuns animals. Lampreys in fine sediment tend to respond to the field around the cathode.

15 Continually observe captured fish for signs of stress and injury (**Table 5**). Reduce pulse width, pulse rate, and/or voltage as necessary if injuries occur.

Table 5 Signs of Electrofishing Stress and Injury in Fish

1. **Stress:** Fish takes unusually long time to recover.
   - Change water in bucket frequently to keep it well oxygenated
   - Hold fish facing upstream in current to move oxygenated water over gills until it swims away.
   - Use dark colored bucket.
   - Keep bucket in the shade.
   - Process and release fish more frequently.
   - Adjust voltage, frequency and/or pulse width down slightly if stress seems unusually high.
   - Fish typically recover.
2. **"Brands", "burns":** Hemorrhages or bruises under skin caused by muscle contraction. Skin with dark blotchy appearance, typically behind dorsal fin or on dorsal side of peduncle.
   - Reduce voltage, frequency, and/or pulse width if more than a few fish have branding.
   - Fish may recover.
3. **Spinal Injuries:** Severe muscle contraction dislocates vertebrae.
   - Reduce voltage, frequency, and/or pulse width.
   - Do not excessively shock fish hiding in confined area.
   - Keep the electrode moving.
   - Fish typically do not recover.

16 Fish behavior and injury in the electric field varies with proximity to the electrode, fish species, and fish size. Larger fish interact with more of the field than smaller fish (**Table 5**). The zone of serious fish injury is usually within 0.5 meters of the anode.

Table 6 Electric Fields and Fish

Distance From Electrode	Fish Behavior
Very Far	No noticeable change: fish does not sense field.
Far	Avoidance: fish senses field and swims away.
Close	Galvanotaxis: fish swims involuntarily towards or away from field on its side.

Distance From Electrode	Fish Behavior
Closer	Narcosis: fish is limp and unconscious.
Very close	Tetany: fish is rigid and unconscious, injury more likely.

17 Avoid fish contact with the electrode. Fish contact with the anode usually causes severe injury or death.

18 Do not crowd the fish in the bucket and change bucket water frequently to maintain well oxygenated, cool water. Cover the bucket with the dip net when changing bucket water to avoid losing fish. Crowding increases fish stress. Keep the bucket shaded to the extent feasible.

19 Stop to process the captured animals periodically. Animals should be processed frequently to minimize stress.

20 When processing fish, move slightly downstream below some natural fish movement barrier, like a riffle, making it unlikely that the same individuals will be recaptured.

21 Set up three buckets for fish processing. One bucket contains the unprocessed fish, a second bucket contains water with an approved anesthesia (if used), and a third bucket holds fresh stream water for fish recovery before release. Follow manufacturer's directions for anesthesia dose and crew safety procedures. Wear rubber gloves, if necessary.

22 Make sure hands are wet, clean, and free of insect repellent and sunscreen. Scrub hands with wet sand, if necessary. Wet the measuring board.

23 Work up ESA listed fish and larger fish first. Scoop a small number of individuals with the small aquarium net and place into the anesthesia bucket.

24 Process promptly when fish become anesthetized. Identify the species, measure the total length to the nearest centimeter, and record on tally sheet. Amphibian lengths are measured from the snout to the anterior part of the vent. Record any injuries or abnormalities (see **Table 5** and **Table 7**).

Table 7 List of Fish and Amphibian Abnormalities

Abnormality Abbreviation	Category	Definition and Description
A	Absent	Eye, fin or tail
BK	Blackening	Tail or whole body with darkened pigmentation
BL	Blisters	In mouth, just under skin
BS	Black spot disease	Extensive small black cysts (dots) over the fins and body
CO	Copepod	Worm like copepod embedded in the flesh; body extends out and leaves a sore/discoloration at base. May be in mouth, gills, and fins or anywhere on body.
CY	Cysts	Fluid filled swellings; either small or large dots
D	Deformities	Skeletal anomalies of the head, spine, and body shape; amphibians may have extra tails, limbs, toes
EF	Eroded fins	Reductions or substantial fraying of fin surface area
EG	Eroded gills	Filaments eroded
F	Fungus	Filamentous or "fuzzy" growth on the fins, eyes or body
FA	Fin anomalies	Abnormal thickening or irregularity of rays
G	Grubs	White or yellow worms embedded in muscle or fins
H	Hemorrhaging	Red spots on mouth, body, fins, fin bases, eyes or gills
I	Ich	White spots on fins, skin or gills
LE	Lesions	Open sores or exposed tissue; raised, granular or warty
LI	Lice	Scale-like, mobile arthropod
M	Mucus	Thick and excessive on skin or gill, or as long cast from vent
O	Other	Anomalies or parasites not specified
SA	Scale anomalies	Missing patches, abnormal thickenings, granular skin
SO	Shortened operculum	Leaves a portion of the gill chamber uncovered
T	Tumors	Areas of irregular cell growth that are firm and cannot be easily broken open when pinched. (Masses caused by parasites can usually be opened easily)
W	Leeches	Attached to body
X	Exophthalmia	Bulging of the eye

25 Place processed fish in the recovery bucket. Release when recovered from anesthesia.

26 Release the animals near the locations they were collected.

27 Some individuals may be slow to recover. Hold the fish facing upstream or gently move it back and forth through the water to cause water to flow over the gills.

28 Collect identification voucher specimens for all sculpins, dace, shiners, suckers, and any other individuals with questionable field identification. Do not intentionally sacrifice ESA listed species or other species of concern. Retain accidentally killed individuals. It should not be necessary to retain voucher specimens of amphibians or large trout. Voucher (verify the identity of) amphibians and larger fish with photographs.

29 Place vouchers for a single species in nylon stocking with a label. Collect more than one of each species. The specimen label should list the species, date, site name, site number, number of individuals vouchered and field crew initials. Place in a plastic bag. Transfer vouchers in nylon stockings to a jar of preservative. Label jar inside and out with the stream name, date, site ID number, and field crew initials.

30 Vouchering with complete and clear labeling is very important. Field identification of many species is tricky. Well-preserved and well-labeled vouchers are essential for data quality.

31 Continue until entire stream reach is surveyed.

32 At the end of the survey record the button time, stop time, electrofisher settings, and other information in the electrofishing log portion of the field form.

33 Record any large individuals or species observed but not captured in the comments section.

34 Record any injuries or mortality of ESA listed individuals on the ESA log form. Briefly record circumstances of injury or mortality and what corrective steps were taken in the electrofishing log portion of the vertebrate field form.

35 Electrofishing is usually the last part of the stream survey. Collect all transect flagging before leaving the site.

36 At the DEQ Laboratory, double check voucher labels. Log voucher specimens into the vertebrate voucher log book. Place vouchers in the designated plastic tub.

Decontamination

It is for field crews to spread fish and amphibian diseases through contaminated equipment. The following guidelines should minimize chances of spreading diseases.

- Rinse off from boots, waders, and equipment before leaving the site. Especially rinse off mud. Allow equipment to dry completely, if possible. Thorough rinsing and drying are probably the most effective steps to minimize disease spread.
- Be especially diligent about equipment hygiene when moving between major drainages and particularly between east and west of the Cascades or when moving from areas known to have whirling disease, like northeast Oregon. Soaking equipment in a 10% chlorine bleach solution for 10 minutes will kill whirling disease spores. Follow by rinsing and drying equipment in the shade. Chlorine is a reactive chemical that can damage equipment with prolonged contact.
- Never transport live or dead fish or amphibians between drainages. Always release collected animals back into the stream reach from which they were

collected.

Voucher Verification

Equipment

- Dissecting microscope
- Light source for microscope
- Dissecting kit
- Fish and amphibian taxonomic references

Procedure

1. A DEQ WA staff person with fish taxonomy expertise examines all voucher specimens under a dissecting microscope. Corrections are made to field data sheets as necessary.
2. All questionable identifications are double-checked by a second DEQ WA staff person.
3. Approximately 10% of the vouchers are re-identified independently by a second DEQ WA staff person, including at least one of each species.
4. Any unresolved voucher identification questions are sent to Dr. Douglas Markle (Fish Museum Curator, Department of Fish and Wildlife, Oregon State University) for identification.
5. Field identification problems are noted for improvement in future field crew training classes.
6. Specimens are retained at the DEQ Laboratory.

Data Entry and Verification Method

1. After vouchers have been identified and field forms have been corrected the vertebrate data is entered into the DEQ biomonitoring vertebrate database.
2. The accuracy and completeness of data entry into the database is verified by comparing paper copies of site vertebrate data in the database with field data sheets.
3. The completeness of data entry in the database is verified by comparing the database entries with the site visit log. Any discrepancies are investigated and corrected.
4. The project monitoring coordinators are responsible for implementing and tracking the data entry and verification protocols.

Quality Assurance

Quality assurance procedures are integrated into the methods presented above. Key QA elements are summarized below.

1. Ten percent of the sites are randomly selected for re-surveying by a different field crew to evaluate field crew sampling variability and season variability.
2. Voucher specimens are collected and re-identified in the lab by a DEQ WA fish taxonomy expert to verify and correct field species identification. At least 10% of these voucher specimens are re-identified by a second DEQ WA fish taxonomy expert. Any problematic specimens are sent to fish taxonomy experts at OSU for identification.

3. Paper copies of electronic data are compared with field data sheets to verify and correct electronic data entry.
4. Site records in the database are compared with entries in the site visit log to verify the completeness of data entry.
5. Voucher verification, data entry and data verification should be completed as soon after the end of the field season as practical.
6. The project monitoring coordinators are responsible for implementing and tracking quality assurance protocols.

Safety

The material in this safety section is taken from Allen-Gill (2000) and Peck (et al. 2000). See the "Working On or Near Water" JSA for further information.
Fish and amphibians are collected using portable electrofishing units that put electric current into the water body that field crews are standing in. Electrofishing units may deliver fatal electric shocks. It is therefore essential that safety procedures be followed at all times. However, it is also important to note that with the modern, well-maintained equipment and well-trained crews used by DEQ the actual risk to the crews from electrofishing is quite small. More fish biologists have been killed driving to the work site than have been electrocuted by electrofishers (Allen-Gill 2000).

- While safety is every crewmember's job, the primary responsibility for crew safety while electrofishing rests with the crew leader (not necessarily the electrofisher operator).
- The single most important safety procedure is that all crewmembers keep each other in verbal and visual contact at all times.
- The electrofisher operator should announce when current is being turned on.
- The electrofisher should be turned off when the crew is moving through fast, deep, or unstable bottom areas where footing and balance may be difficult.
- The electrofisher operator should be ready to shut off the current and remove the anode from the water if crewmembers are having trouble maintaining balance.
- Do not electrofish areas that are unsafe due to fast or deep water. Note these areas on the vertebrate survey field sheet.
- Know first aid and cardio-pulmonary resuscitation. Know the location of the nearest hospital or emergency care facility.
- Avoid electrofishing near any unprotected people, pets, or livestock.
- Crewmembers must be insulated from contact with the water. Crewmembers should wear waders with non-slip soles, and rubber electrician's gloves. Gloves and waders should be dry on the inside. Crewmembers who perspire heavily may benefit from wearing polypropylene long underwear to wick moisture away from the skin.
- Avoid un-insulated contact with the water. Reach into the water with an ungloved

hand to retrieve a stunned fish or other object only after verifying with the electrofisher operator that the current is off and the anode removed from the water.

- Avoid contact with the electrodes.
- Avoid contacting logs, tree, or boulders with un-insulated hands, particularly when they are wet.
- Do not electrofish during heavy rain.
- Use electrofishing equipment that is in good repair.
- Do not make any modifications to the electrical operation of the electrofisher, especially the thumb switch and tilt shut-off switch.
- Hold the thumb switch down in the reversed (off) when not electrofishing to avoid unintentionally depressing the thumb switch to the on position. Turn the electrofisher off at the main switch if both hands are needed for some activity when not electrofishing.
- An almost universal feature of electrofishers is to have netting attached to the anode ring. This feature greatly increases fish collection efficiency from using the anode net to transfer stunned fish to the fish bucket. However, this feature also makes it more likely that the bucket holder could be shocked if the live electrode makes contact with the metal bucket handle or the crewmember's hand. The crewmember carrying the bucket should wear electrician's gloves.
- Sealed, gel-filled lead-acid batteries power the electrofishers. Do not drop or handle these batteries roughly, as this could crack the battery. Make sure that the batteries are placed in the vehicles so they cannot move around in transport and become damaged.
- If battery housing becomes cracked the acid gel electrolyte may leak out. This gel is highly corrosive. Avoid contact with the gel. Wear gloves and eye protection when cleaning up.
- Avoid skin contact with the ethanol and formalin used to preserve vouchers specimens. Use with adequate ventilation. Transport and store ethanol jugs and voucher jars in a cooler or other sealed container to contain fumes and leaks.

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CHAPTER 4 – FIELD ANALYTICAL METHODS

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pH

Background

Water pH is critical to fish because it can affect fish egg production and survival, aquatic insect survival and emergence, and the toxicity of other pollutants such as heavy metals or ammonia (Oregon Plan for Salmon and Watersheds, 1999). Like water temperature, pH varies daily and seasonally.

In Oregon the pH values of natural waters run in the range of 6 to 9, excluding some highly alkaline closed lake systems in southeast Oregon. pH levels above 9.0 and below 6.5 may have an adverse effect on some life cycles of salmonids and aquatic macro invertebrates. pH is of particular concern in areas contaminated with heavy metals, as low pH can greatly increase their mobility. Indirect effects of pH on stream chemistry result from the interaction between pH and a variety of other chemical equilibria. For example, at 5° C the equilibrium concentration of un-ionized ammonia can increase tenfold with a change of pH from 6.5 to 7.5.

When acids dissolve in water, hydrogen ions (H^+) are produced. Hydrogen ion concentrations in water usually comprise very small fractions — 1/10,000,000, in water with a pH of 7. For convenience, these concentrations are converted to a pH scale—a logarithmic numerical scale that ranges from 0 to 14. Pure water has a pH of 7, and is the neutral point—neither *acidic* nor *basic*. Water is acidic when the pH value is below 7 and basic (or alkaline) when the pH value is above 7. Note that a unit change in pH is a tenfold change in hydrogen ion concentration. It is important to understand the terms alkalinity and acidity refer not to the pH, but rather to the ability of the solution to neutralize acids and bases respectively.

Most daily cycles in pH occur as a result of the photosynthesis of aquatic plants. The chemical reaction governing changes in pH related to photosynthesis is (Equation 1):

$$CO_2 + H_2O \rightleftharpoons [H_2CO_3] \rightleftharpoons H^+ + HCO_3^- \quad (1)$$

Carbon dioxide and water are in equilibrium with carbonic acid, which is in equilibrium with hydrogen ions and bicarbonate ions. Through photosynthesis, plants convert the sun's energy into chemical products they need to live and grow. During daylight hours, aquatic plants convert carbon dioxide into sugar. This consumption of carbon dioxide causes a conversion of carbonic acid and hydrogen and bicarbonate ions towards carbon dioxide to restore equilibrium. This conversion of hydrogen ions raises pH. Consequently, water becomes more basic during the day (pH values get higher) and usually peaks in mid-to-late afternoon. Virtually all aquatic organisms produce carbon dioxide (acid) through their normal metabolism of food (respiration). During respiration, the addition of carbon dioxide shifts the equilibrium towards the production of hydrogen ions (and bicarbonate ions). As a result, water becomes more acidic during the night (pH values drop) and usually is lowest just before sunrise. A similar daily pattern occurs in dissolved oxygen concentrations because of photosynthesis.

Water pollution can cause changes in pH through the direct addition of acids or bases such as acid mine drainage, acid rain, or chemical spills. More commonly, pH is altered by excessive plant growth that results from the addition of nutrients. Nutrients end up in our waterways from sewage or industrial discharges, failing septic systems, and agricultural and urban runoff.

pH is measured by the electrometric method as defined in Standard Methods (American Public Health Association, et al., 1998, section 4500- H^+).

pH Theory

pH is commonly defined as the negative log of the concentration of hydrogen ions in water in moles per liter. Common measurement techniques for pH are based on the hydrogen ion activity, and do not directly measure hydrogen ion concentration. pH is defined as (Equation 2):

$$pH = -\log A_{H^+} = -\log [H^+]\gamma_{H^+} \quad (2)$$

where A_{H^+} refers to the hydrogen ion activity, $[H^+]$ refers to the concentration of hydrogen ions in moles/L and γ_{H^+} refers to the activity coefficient. γ_{H^+} is a function of ionic charge, ionic size, ionic strength, and temperature. γ_{H^+} can be computed using the temperature-dependent form of the extended Debye-Hückel equation (Harris, 1991), which is beyond the scope of this topic. Ionic charge and size are considered constant, at values of –1 and 900 picometers, respectively for the hydrogen ion.

Ionic strength, μ, is defined as (Equation 3):

$$\mu = \sum_i C_i Z_i^2 \quad (3)$$

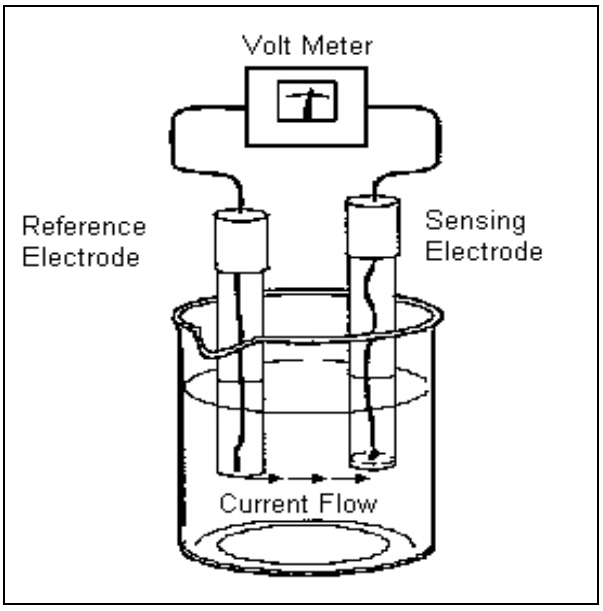
where C_i is the concentration of the *i*th species and Z_i is its charge. The sum extends over *all* ions in solution. The greater the ionic strength of a solution, the less attraction exists between oppositely charged ions and the lower the activity coefficient. At 25°C, γ_{H^+} ranges from 0.83 at ionic strength of 0.1M to 0.967 at ionic strength of 0.001M, to 1 at ionic strength of 0 (Harris, 1991). At zero ionic strength, measurement of pH is actually measurement of hydrogen ion concentration.

Hydrogen ion activity varies with temperature, but is not a simple linear relationship. At the low ionic strength of ambient water quality, temperature effects on hydrogen ion activity are negligible. Temperature has a more significant effect on acid/base disassociation, as seen in the variance of pH with temperature in buffer solutions. Temperature also changes pH electrode slope. For these reasons, an automatic temperature compensation probe is used in conjunction with a pH electrode.

Measurement Concepts

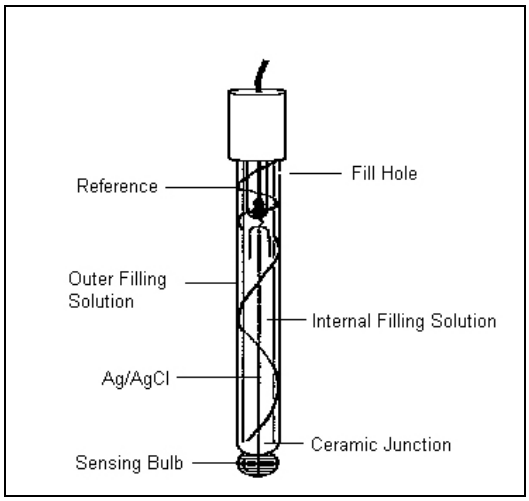
pH electrodes calculate the pH of a solution using the measurement of an electric signal (potentiometry). **Figure 1** illustrates a basic potentiometer.

Figure 1 Basic Potentiometer



When a pH-sensing electrode comes in contact with a sample, an electric potential develops across a membrane on the surface of the sensing electrode. The membrane potential varies with the pH. Making a measurement requires a second unvarying electric potential to quantitatively compare the changes of the sensing membrane potential. A reference electrode provides this function. Modern pH probes combine the sensing and reference electrodes into a single combination electrode (**Figure 2**). The sample electric potential develops across the ceramic junction.

Figure 2 Combination Electrode



Electrode behavior is described by the Nernst equation (Equation 4):

$$E_{measured} = E_0 + (2.3*RT/nF) \log A_H^{+} \qquad (4)$$

$E_{measured}$ is the measured potential from the sensing electrode, E_0 is related to the potential of the reference electrode, 2.3*RT/nF is the Nernst factor, and $\log A_H^+$ is the (negative) pH. The Nernst factor includes the Gas Law constant (R), Faraday's constant (F), the temperature in degrees Kelvin (T) and the charge of the ion (n). For pH, where n = 1, the Nernst factor is 2.3*RT/F. Since R and F are constants, the Nernst factor and therefore electrode behavior is dependent on temperature.

Microprocessor-controlled pH meters contain pH versus temperature values for commonly used buffers. This allows the meter to recognize a particular pH buffer and calibrate with the correct value. When a pH meter detects the sensing electrode signal, reference signal and the temperature, the meter software calculates the pH using the Nernst equation.

pH probes are extremely sensitive and must be handled carefully to avoid breakage or fouling. Ensure that the probe is placed in solution so that the sensing bulb is at a level above any stirring device. Place the probe at least 1 cm, but not more than 2 cm, into the solution. This will ensure that the ceramic junction is submerged in the solution. This will also ensure that the level of Reference Electrode Filling Solution in the probe is high enough to provide a hydraulic head. Such a head will force filling solution through the ceramic junction, rather than allow sample solution to diffuse into the junction. The glass probe and ceramic junction tend to store or "remember" ions from samples with high ionic strength. This could cause subsequent "clean" samples, or samples with low ionic strength, to read improperly. After exposing the pH probe to high activity samples, such as Electrode Storage Solution, pH buffer, alkalinity samples, or other samples with high conductivity, ensure that the probe is properly rinsed before recording a measurement.

Quiescent measurements are performed to improve the stability of the pH readings. Clean water samples have relatively low ionic strength and are therefore poor electrical conductors. These low-level ionic strength samples act as "antennae", which results in a noisy electrode response. Quiescent measurements are made to minimize this effect. In addition, adding a pH Ionic Strength Adjuster (pHISA) solution to the sample increases the ionic strength, thus reducing noise and improving response time. The shift in pH caused by the addition of pHISA is minimal, between 0.005 and 0.01 SU (Orion Research, Inc., undated).

Equipment and Supplies

- pH meter: Meters available include Beckman Φ 11, Beckman Φ 200, Beckman Φ 250, and Orion 210A. All meters are equipped with the Orion/ROSS model 8102 Combination pH electrode and Automatic Temperature Compensation Probe.
- Magnetic stirrer and stirbar
- 250-mL beaker
- 100-mL graduated cylinder
- pH buffer solutions: 4, 7, and 10; referenced to NIST Standard Reference Materials. Secondary containers of pH buffer solution must be labeled with the type of solution, date the container was filled, and analyst's initials.
- Low Ionic Strength (LIS) Buffer: sulfuric acid buffer (0.00001 N) supplied by the Lab's Organic Section.
- pH Ionic Strength Adjustment (pHISA) solution, (7% KCl). Purchased or prepared by the Lab's Organic Section.
- 1-mL syringe injectors, for use with purchased pHISA, or 1-mL eyedropper and

bottle for lab-prepared pHISA.

- Ross pH Reference Electrode Filling Solution (3M KCl)
- Orion pH Electrode Storage Solution (a buffered KCl solution)

Expired reagents affect analytical results!

Ensure that reagents, buffers, and standards are not beyond their expiration date (as indicated on the container) or otherwise appear contaminated.

pH buffers: When using pH buffers directly from the primary container, observe the manufacturer's expiration date. Expiration date for secondary containers is one year from the fill date.

LIS buffer and pHISA: Expiration date is six months from the fill date.

Calibration and Standardization

Instrument calibration procedures may differ slightly, so it is important to follow manufacturer's instructions. The most critical component of the pH meter is the probe. Instruction manuals for the pH meter and the ROSS electrode, and an instrument logbook are found in each instrument case.

Record All Calibration and Maintenance in the logbook. Also record your initials, the date, time, project, your physical location if in the field, buffers used, buffer temperature, and any adjustments, probe replacement, battery changes, etc.

CHEMICAL SAFETY

To minimize the hazards of chemical exposure, handle all chemicals using safety goggles (with elastic band) and PVC gloves. To minimize chemical spills, handle the chemicals with caution and ensure container lids are tightly fastened. Be cognizant of laboratory safety manual, chemical hygiene plan, and emergency operations plan (especially spill procedures).

Daily Electrode Care:

Use the correct filling solution in the probe. The probes will be useless if the wrong solution is used. The ROSS 8102 electrode uses ROSS Reference Electrode Filling Solution (Orion Cat. No. 810007). It is an orange colored solution of 3M KCl.

The pH bulb should never be allowed to dry out. When sampling relatively "clean" water such as during typical ambient river monitoring; the probe should be stored in a beaker of river water while in transit to the next sampling site. If the probe will not be used for several hours, it is preferable to use Orion pH Electrode Storage Solution (a buffered KCl solution). Electrode storage solution must be used for overnight storage, and for storage at the Lab. Storage solution should be changed weekly or sooner if it becomes contaminated. Each probe is supplied with a storage bottle – make sure the bottle contains enough solution to cover the pH bulb and reference junction.

Daily Calibration Check:

Prior to going in the field, and at the start of each field day, check the pH meter calibration using two buffers in the pH range of the expected sample water. Always use buffer 7.0, and either buffer 4.0 or 10.0 depending on the expected range. The Beckman Φ 250 can calibrate to three buffers. When using a meter capable of three-point calibration, it is important to use this feature especially when alkalinity titrations will be performed. Naturally alkaline waters will be titrated to acidic conditions, and calibrating the meter for acidic, neutral, and alkaline conditions will improve results of both the pH and alkalinity analyses. Be sure to use the automatic temperature compensation probe, and to slowly stir all buffers and samples. The instrument should read within 0.1 pH units of the buffer's value at the given temperature (see chart on buffer bottle).

Buffers should be replaced frequently depending on use. In no case should they be kept more than one year after transferring buffers from their original packaging to field containers. Frequent and routine use of buffers will eventually cause biological contamination of the buffers and possible buffer dilution.

1. Check the level of the filling solution in the probe. If it is 2 cm or more below the opening, add more filling solution.
2. Check for crystal formation in the electrode body. Small amounts of crystal are tolerated. However, if more than 1 cm of crystals is observed, empty out the electrode, rinse with warm deionized water to dissolve the crystals, then refill with the appropriate filling solution.
3. Observe the electrode bulb for any dirt or damage. Clean if dirty and replace if damaged. Follow cleaning instructions as presented in the pH electrode instruction manual.
4. Open the electrode vent plug during calibration and sample measurement.
5. Rinse the electrode and ATC probe with deionized water, and then immerse the bulb and ATC probe in pH 7.0 buffer. Make sure the reference junction is at least 1 cm but not more than 2 cm below the surface. (Always use pH buffer 7.0 first, which is the electrode's isopotential point.) Slowly stir the buffer.
6. Wait for a stable reading, stop stirring, and allow the probe to equilibrate. Then record the buffer temperature and instrument reading in the logbook.
7. Clean the pH probe with deionized water between buffers.
8. Repeat steps 5 and 6 for the 2nd buffer (and again for the 3rd buffer when using the Beckman Φ 250), and record the temperature and reading in the logbook.
9. The instrument should read within 0.1 pH units of any buffer value. If not, try again with fresh buffer solution. If still unsuccessful, perform a 2-point (or 3-point whenever possible) calibration following the instrument's instruction manual and repeat the daily calibration check. If the probe fails calibration, then it should not be used. Make a note in the logbook and set the probe aside to be cleaned and serviced following the manufacturer's instructions.

Low Ionic Strength Check:

This procedure is only done in the lab, prior to taking a pH meter in the field. A common problem with the pH measurement is with fouling at the ceramic junction of the glass electrode. Because of the high conductivity of standard buffer solutions, this liquid junction fouling can not be detected during calibration. The only way to detect fouling at the liquid junction is to use a low ionic strength buffer.

This is a rigorous test -- the low ionic strength (LIS) buffer has a specific conductance of about 5 µmhos/cm, which is much lower than the conductance of typical water samples. The buffer is provided in glass-stoppered bottles with the pH indicated on the label. The typical pH is 5.0.

1. Rinse the probes with deionized water, then with low ionic strength buffer (LIS).
2. Place the probes in fresh LIS and stir slowly.
3. Wait up to 10 minutes for the reading to stabilize. Turn off the stirrer, and allow the probe to equilibrate. The instrument should read within 0.5 units of the LIS buffer value. If not, try again with fresh LIS buffer. If still unsuccessful, ensure that the instrument can read a pH 4.0 buffer, recalibrate the meter as necessary, and repeat the LIS check. If the probe fails the LIS test, then it should not be used. Make a note in the logbook and set the probe aside to be cleaned and serviced following the manufacturer's instructions.

Annual Temperature Check:

Once per year, at the beginning of the year, the Automatic Temperature Compensation (ATC) Probe is checked against a NIST-traceable thermometer in a variety of water baths. See the Temperature Section for the procedure. Record all results in the instrument logbook.

Methods

1. Open the pH probe's fill hole.
2. Rinse the probes (pH and ATC) with DI water. Never allow DI water to enter the fill hole.
3. Thoroughly rinse a beaker with DI water or sample water. This is particularly important after an alkalinity titration, since any residual titrant can lower the pH of the next sample.
4. Pour approximately 100 mL of water sample in a beaker. If the sample will be tested for alkalinity, measure the100 mL with a graduated cylinder for a precise volume.
5. Add 1 mL of pHISA solution per 100 mL of sample (this will increase the specific conductance by approximately 1300 µmhos/cm). The pHISA is a KCl solution and will not affect sample alkalinity. This step is performed on all samples for standardization.
6. Place the probes in the sample. Make sure that the ATC probe and the ceramic junction on the pH probe is submerged at least 1 cm but not more than 2 cm. Never submerge the fill hole of the pH probe.
7. Slowly stir the sample, preferably with a magnetic stirrer, for at least three minutes. Allow probe to equilibrate in sample water. Note: Stirring too rapidly will introduce air bubbles, and will cause a "streaming effect" on the glass electrode. This tends to cause an erroneously low readout.
8. Turn off the stirrer, and allow the probe to equilibrate before checking the reading.
9. Stir one minute more and check the reading again.
10. Repeat steps 2 through 9 if the sample immediately follows another sample with significantly different ionic activity, e.g., storage solution, buffer solution, alkalinity sample, DI water, samples with significantly higher or lower conductivity.
11. When a stable reading is achieved, record the result to the nearest 0.1 SU.
12. Store the probe as directed above (Daily Electrode Care).

Calculations and Data Reporting

pH measurement is accurate to ± 0.1 SU. Report pH results to the nearest 0.1 SU.

References

American Public Health Association, American Water Works Association, and Water Environment Federation, 1998. Standard Methods for the Examination of Water and Wastewater (20^{th} Edition), section 4500- H^+. American Public Health Association, Washington, DC.

Harris, Daniel C., 1991. Quantitative Chemical Analysis (Third Edition). W. H. Freeman and Company, New York.

Oregon Plan for Salmon and Watersheds, 1999. Water Quality Monitoring Guidebook, Version 2.0. Oregon Plan for Salmon and Watersheds, Salem, Oregon.

Orion Research, Inc., undated. Technical Bulletin 501 – pH Measurement in Low Ionic Strength Solutions. Orion Research, Inc., Beverly, MA.

ALKALINITY

Background

The alkalinity of water is its quantitative capacity to neutralize a strong acid to a designated pH. It is primarily a function of the water's carbonate, bicarbonate, and hydroxide concentrations, although other constituents such as borates, phosphates, and silicates may contribute as well.

Samples are titrated with 0.020N H_2SO_4 to a potentiometrically (using the pH meter and electrodes) determined end point, the value of which is dependent on the total carbonate concentration (American Public Health Association, et al., 1998, section 2320). Since environmental water samples are known or suspected to contain silicates or phosphates, the endpoint is pH = 4.5. If alkalinity is less than 20 mg/L, a low level alkalinity method is used. The practical range of alkalinity is 1 mg/L to 500 mg/L.

Equipment and Supplies

- pH meter: Meters available include Beckman Φ 11, Beckman Φ 200, Beckman Φ 250, and Orion 210A. All meters are equipped with the Orion/ROSS model 8102 Combination pH electrode and Automatic Temperature Compensation Probe.
- Automatic self-zeroing 25-mL acrylic buret with 500-mL squeeze bottle & tubing for ground water samples.
- Automatic self-zeroing 10-mL acrylic buret with 500-mL squeeze bottle & tubing for surface water samples.
- 500-mL beaker for ground water samples
- 200-mL beaker for surface water samples
- 100-mL graduated cylinder
- Magnetic stirrer
- Magnetic stirbar
- Sulfuric acid titrant (0.02N): Prepared by Organic Section of the Laboratory.

Expired reagents affect analytical results!

Ensure that reagents, buffers, and standards are not beyond their expiration date (as indicated on the container) or otherwise appear contaminated.

Titrant: Expiration date is six months from the fill date.

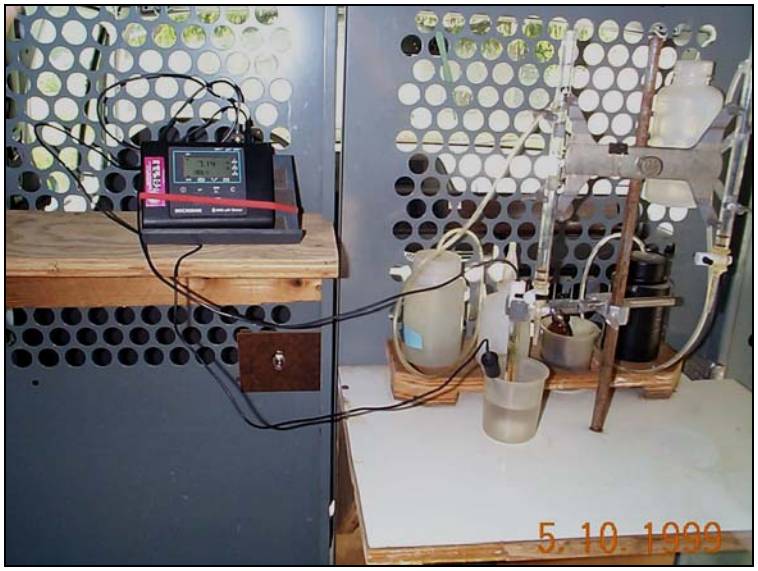
Calibration and Standardization

See the pH section for instructions on calibrating and maintaining the pH meter and electrodes.

Methods

Figure 3 demonstrates a typical field alkalinity benchtop set-up.

Figure 3 Field Alkalinity Set-up



Prior to the first alkalinity titration of the day, drain and refill the automatic buret containing the sulfuric acid titrant. This prevents the use of contaminated titrant. Drain some fresh titrant through to ensure no bubbles remain in the buret tip. Examine the buret and tubing. Replace the tubing if it is dirty or cracked. Dirty burets can cause as much as 0.1 mL of titrant to adhere to the buret wall. Replace dirty burets or return to the lab for a cleaning with an alcoholic-KOH solution so that the buret drains smoothly and the meniscus is satisfactory.

1. Pre-rinse a beaker with distilled water and/or sample water. Use a 200-mL beaker for surface water or a 500-mL beaker for groundwater. The beaker size is important to make sure the sample doesn't overflow when titrant is added.
2. Measure 100 mL of sample with a graduated cylinder and pour it in the beaker.
3. Measure the pH as described in the pH section; making sure that the titrant does not drop into the sample.
4. Fill and zero a buret with 0.02 N H_2SO_4 alkalinity titrant.

CHEMICAL SAFETY

To minimize the hazards of chemical exposure, handle all chemicals using safety goggles (with elastic band) and PVC gloves. To minimize chemical spills, handle the chemicals with caution and ensure container lids are tightly fastened. Be cognizant of laboratory safety manual, chemical hygiene plan, and emergency operations plan (especially spill procedures).

5. Stir the sample with a magnetic mixer throughout the titration. Excessive stirring or agitation of the sample should be avoided, because it may introduce CO_2 into the sample and thus effect pH measurements. Keep the depth of the stir-vortex to about ¼ inch.
6. Add titrant to the sample until the pH 4.5 end point is reached.
    - The endpoint pH is measured on quiescent samples only. After the titrant has been added and mixed thoroughly, turn stirrer off and wait for reading to stabilize.
    - If titrant used is less than 2.0 mL (alkalinity < 20 mg/L), see the ***Low Level Alkalinity Procedure*** outlined in step 7.
    - If greater than 50.0 mL of titrant are required for titration, repeat the analysis using smaller sample volume.
1. ***Low Level Alkalinity Procedure***: If the volume of titrant used to reach the endpoint (pH = 4.5) is less than 2.0 mL (alkalinity < 20 mg/L), then note the pH and the volume of titrant used. Carefully add additional titrant to reduce the pH exactly 0.30 units and again note the volume. Use the ***Low Level Alkalinity Calculation*** given below.

Calculations and Data Reporting

Note the amount of titrant used to the nearest 0.1 mL. Each 0.1 mL of titrant equates to 1.0 mg/L of alkalinity as $CaCO_3$. Therefore,

Alkalinity as $CaCO_3$ (mg/L) = titrant volume (mL) * 10 (Eq. 1)

Report results to the nearest mg/L as $CaCO_3$. The method detection limit is approximately 1.0 mg/L.

Low Level Alkalinity Calculation

Alkalinity as $CaCO_3$ (mg/L) = (2B - C) * 10 (Eq. 2)

Where:

B = mL titrant to first recorded pH and

C = total mL titrant to reach pH 0.30 unit lower.

As an example, if it took 1.3 mL to reach the end point of 4.5 pH units and an additional 0.2 mL to reduce pH by 0.30 units,

then B = 1.3, C = 1.5 and

Alkalinity = [(2*1.3mL) – 1.5mL] * 10 = (2.6mL – 1.5mL) * 10 = **11 mg/L as $CaCO_3$**.

References

American Public Health Association, American Water Works Association, and Water Environment Federation, 1998. Standard Methods for the Examination of Water and Wastewater (20th Edition), section 2320. American Public Health Association, Washington, DC.

TEMPERATURE

Background

Stream temperature is one of the most important environmental factors affecting aquatic ecosystems. The vast majority of aquatic organisms are poikilothermic -- their body temperatures and hence their metabolic demands are determined by temperature. Temperature has a significant effect on cold-water fish, both from a physiological and behavioral standpoint. Below is a brief list of the physiological and behavioral processes affected by temperature (Spence et al., 1996).

- Metabolism
- Food requirements, appetite, and digestion rates
- Growth rates
- Developmental rates of embryos and alevins
- Timing of life-history events, including adult migrations, fry emergence, and smoltification
- Competitor and predator-prey interactions
- Disease-host and parasite-host relationships

Water temperature also affects the concentration of dissolved oxygen (DO) and a temperature measurement is needed to calculate the DO percent saturation of a water sample. Water temperature is influenced by weather (solar radiation, wind, humidity, etc), channel morphology, substrate type, stream orientation, topography of the surrounding area, groundwater interactions, and streamside vegetation characteristics. Point source discharges and land use practices that alter stream morphology or streamside vegetation may affect water temperature in streams.

The WA section measures temperature in grab samples and conducts long-term studies in which temperature is measured continuously with data loggers. Continuous temperature data collection techniques are described in Chapter 5. This section describes the techniques for measuring temperature in grab samples collected as part of standard field parameter measurements and for auditing continuous temperature monitoring devices.

Equipment and Supplies

Laboratory Use

- Eutechnics Model 430 digital thermometer with Eutechnics stainless steel probe

The Eutechnics thermometer with stainless steel probe is National Institute of Standards and Technology (NIST)-certified by Eutechnics and is used **only in the laboratory** for accuracy-checking thermometers and data loggers.

Field Use

- VWR digital thermometer
- Eutechnics Model 430 digital thermometer with YSI series 400 thermistor probe
- YSI Model 30 conductivity meter

Each of these thermometers is NIST-traceable via the Eutechnics (NIST-certified) thermometer with stainless steel probe. Eutechnics thermometers are ten times more accurate than the VWR digital thermometers and the thermometer on the YSI Model 30 conductivity meter.

Calibration and Standardization

Digital thermometers should be checked annually for accuracy. This may be done in house, as described below, or by an outside source such as the thermometer manufacturer or an electronics testing laboratory. In-house accuracy checks are recorded chronologically in temperature check notebooks. The NIST-certified thermometer should be sent to Eutechnics annually for re-certification to NIST traceability standards.

Annual Temperature Check for NIST-traceable thermometers:

1. Set up five water baths in five separate coolers, at approximately 5, 10, 15, 20 and 25 °C. Monitor these temperatures with the NIST-certified thermometer. Adjust temperatures with ice and warm water as necessary. Make sure all ice is melted and that temperatures of the baths are stable.
2. Record in the temperature check notebook for the appropriate year :
   - the date and operator of the procedure
   - the purpose of the test
   - the temperature recorded by each NIST-traceable thermometer
   - the temperature recorded by the NIST-certified thermometer
3. If NIST-traceable thermometer temperatures are not within 0.5 °C of the NIST-certified thermometer temperature, return the NIST-traceable thermometer to the manufacturer for servicing.
4. Affix a sticker to the back of the NIST-traceable thermometer with the operator's signature, date, and range of temperatures over which the accuracy of the thermometer was tested.

Methods

Before going into the field, make sure the thermometer you intend to use is not overdue for its annual temperature check. Temperature may be measured *in situ*, or in a sample collection device, such as a bucket. Measure temperature of a sample in a bucket as soon as practical after the bucket is removed from the water.

1. Immerse probe in water sample or in water body and allow temperature to stabilize.
2. When auditing continuous temperature data loggers, make sure to place the probe as close as safely possible to the thermistor on the continuous monitoring device so measured temperature differences will not be the result of spatial variation.
3. When auditing continuous temperature data loggers, measure temperature within five minutes of the most recent logging time.
4. Set digital thermometer to display Celsius degrees, if necessary.
5. Record temperature.

Calculations and Data Reporting

Report temperature in Celsius degrees to the nearest 0.1° C.

References

Oregon Department of Environmental Quality. 1995. Temperature: 1992-1994 water quality standards review, report of the State of Oregon Technical Advisory Committee, Policy Advisory Committee, Temperature Subcommittee, Oregon DEQ, Portland, OR.

Oregon Department of Environmental Quality. 1996. Procedural guidance for water temperature monitoring. Oregon DEQ, Portland, OR.

Spence, B.C., G.A. Lomnicky, R.M. Hughes, and R.P. Novitzki, 1996. *An Ecosystem Approach to Salmonid Conservatio*n. TR-4501-96-6057, Management Technology, Corvallis, OR.

CONDUCTIVITY AND SALINITY

Background

Conductivity of a fluid is a measure of the fluid's ability to conduct an electric current, a property that increases with increasing temperature and dissolved ions. *Ionic strength* is another term used to describe the amount of dissolved ions in water. Conductivity is expressed either in units of µmhos/cm or µsiemens/cm. These units are equivalent, the siemen (S) is the Système International (SI) unit, but "mhos" is used by Standard Methods (APHA, et al., 1998). Conductivity varies with temperature (approximately 2% with each 1°C change) and should be reported as specific conductance, i.e. the conductivity normalized to 25 °C. Salinity, generally reported in parts per thousand (ppth, although incorrectly represented by the YSI Model 30 as ppt), is the measurement of the mass of salts in a given mass of solution. There is a temperature dependent mathematical relationship between conductivity and salinity. The relationship is built on an initial assumption that a standard solution of seawater, of a given conductivity at 15°C, has a salinity value of 35. For more detail on the relationship between salinity and conductivity, refer to American Public Health Association, et al., 1998, section 2510.

Equipment and Supplies

- YSI Model 30
- YSI Model 33
- Secondary standards (147 µmhos/cm and ~1413 µmhos/cm)
- NIST traceable primary standard, 100 and 1,000 µmhos/cm
- Salinity standard, 33 ppth

Two instrument models are in use: the Yellow Springs Instruments (YSI) Model 30, a digital instrument, and the YSI Model 33, an analog instrument. Instruction booklets are in the case with each meter and should be read prior to meter use. The YSI Model 30 is most commonly used because of the convenience of automatic temperature compensation. The YSI Model 30 conductivity meter is equipped with a thermometer traceable to the National Institute of Standards and Technology (NIST). This meter only performs temperature compensation at temperatures at or above 2°C. Below this temperature, the meter must be used in non-temperature compensating mode and the specific conductance calculated manually (see Calculations and Data Reporting, below). The YSI Model 33 meter does not automatically compensate for temperature.

The YSI Model 30 displays measurements as microsiemens (µS)/cm up to 5000 µmhos/cm. Conductance values greater than 5000 µmhos/cm are displayed as millisiemens (mS)/cm. The YSI Model 33 displays measurements in units of µmho/cm.

Organic laboratory staff makes up 5-gallon batches of secondary conductivity standard in two concentrations, 0.001 N KCl (~147 µmhos/cm) and 0.01 N KCl (~1413 µmhos/cm). One-liter bottles of the secondary standards are stored in the field instrument calibration room.

Calibration and Standardization

Conductivity meters are calibrated at the factory, but it is necessary to check the accuracy against a secondary standard solution. For surface water monitoring, use the 147 µmhos/cm secondary

standard. For groundwater and higher ionic strength surface waters, also check the meter in the 1413 µmhos/cm secondary standard after checking in the lower concentration standard. For monitoring saline waters, check the meter in the 33 ppth salinity standard. **Never place the probe in the original bottle of standard solution unless the container will be emptied after use.**

Expired reagents affect analytical results!

Ensure that reagents, buffers, and standards are not beyond their expiration date (as indicated on the container) or otherwise appear contaminated.

Accuracy Check Procedures for YSI Model 30:

1. Turn on the meter and rinse the probe in distilled or deionized water.
2. Rinse the probe with the secondary conductivity or salinity standard solution.
3. Pour about 200 mL of secondary standard solution into a clean beaker and immerse the probe. Make sure the temperature and conductivity sensors are fully submerged (i.e. the oval vent hole is submerged).
4. Depress the MODE button until the "°C" is flashing in the lower right portion of the display. The meter is now in temperature compensating mode. If checking salinity, depress the MODE button until the display reads “ppt”. NOTE: The YSI Model 30 incorrectly displays the units of parts-per-thousand as “ppt”. Record results with units of “ppth” to ensure proper representation in LIMS and LASAR.
5. Agitate the probe vertically in the solution to dislodge air bubbles from the electrode compartment, but do not allow probe to contact the walls of the container.
6. Allow the temperature to stabilize and record the solution’s temperature.
7. Record the conductance or salinity reading.
8. If the reading varies more than 5% from the standard, complete one or all of the following procedures, as necessary, re-checking in fresh secondary standard after each procedure:
   a. rinse the probe with distilled water and fresh secondary standard
   b. turn off the temperature compensation and calculate the specific conductance manually (not applicable to salinity)
   c. allow the secondary standard to warm up to at least 10°C
   d. clean the probe as described in the equipment instruction book.
9. If the reading still varies by 5%, but less than 7%, the meter can still be used in the field, but should be replaced by a backup if one is available.
10. If the conductance reading still varies by more than 7% from the secondary standard value, recalibrate the meter on a primary NIST traceable standard (if in the laboratory) as described in the equipment instruction book. If in the field, use a backup meter if available, or do not use instrument. DO NOT calibrate the meter on a secondary standard.
11. Record in the instrument log book:
    a. the date and operator of the accuracy check or calibration
    b. the location of the check (lab or sampling location)

c. the standard value, temperature, reading of the instrument, and percent difference of the instrument reading from the standard value

12. Rinse the probe thoroughly with deionized water, making sure to direct the rinse water into the electrode ports.

LABORATORY CHEMICAL SAFETY

The cleaning procedure described in the Model 30 instruction manual includes use of 10 N hydrochloric acid. When mixing and using the cleaning solution, wear safety goggles and gloves. Be cognizant of laboratory safety manual, chemical hygiene plan, and emergency operations plan (especially spill procedures).

Accuracy Check Procedures for YSI Model 33:

The mass of the probe on the YSI Model 33 meter is sufficient to affect sample temperature. Protect the probe from temperature extremes by keeping the probe out of direct sunlight and keeping the probe insulated in the meter case on especially cold or hot days.

1. With the meter off, adjust the meter to zero, if necessary, by turning screw on meter face so that meter needle coincides with zero on the conductivity scale.
2. Assure that the probe connection is thoroughly inserted into the probe jack at the lower left portion of the meter.
3. Turn the meter selector knob to REDLINE. Check the meter's battery voltage by adjusting the meter needle to the redline using the REDLINE control knob. If the meter cannot be redlined, replace the batteries.
4. Rinse the probe in distilled or deionized water.
5. Rinse the probe with the secondary conductivity or salinity standard solution.
6. Pour about 200 mL of secondary standard solution into a clean beaker and fully submerge the probe.
7. Agitate the probe vertically in the solution to dislodge air bubbles from the electrode compartment, but do not allow probe to contact the walls of the container.
8. Turn the meter selector knob to TEMPERATURE and read the temperature of the solution on the bottom of the scale.
9. Turn the meter selector switch to X1, X10, or SALINITY, depending on the secondary standard solution measured. If measuring the salinity standard solution, adjust the temperature knob in the upper right portion of the meter face to the measured temperature of the sample. Allow the meter to stabilize before reading.
10. Depress the cell test button when in the x10 and x100 scales (doesn't apply to x1 or Salinity scale) and make sure that the meter reads within 2% of the reading from step 9. If there is a discrepancy greater than 2%, the probe needs cleaning or else the instrument needs servicing and should not be used.
11. Calculate the specific conductance of the standard with the temperature correction table in the front of the logbook. Multiply conductance from the meter by the temperature correction factor to calculate specific conductance at 25°C.

12. Record in the instrument log book:
    a. the date and operator of the accuracy check or calibration
    b. the location of the check (lab or sampling location)
    c. the standard value, temperature, conductance or salinity reading from the instrument, temperature correction factor, calculated specific conductance, and percent difference of the instrument reading from the standard value
13. If the conductance or salinity reading varies more than 5% from the standard, complete one or both of the following procedures, as necessary, re-checking in fresh secondary standard after each procedure.
    - rinse the probe with distilled water and fresh secondary standard
    - clean the probe as described in the equipment instruction book
14. If the reading still varies by 5%, but less than 7%, the meter can still be used in the field, but should be replaced by a backup if one is available.
15. If the reading varies by more than 7% from the secondary standard value, do not use the instrument.
16. Include calibration check results on the calibration plot (% difference) in the back of the log book.

Annual Calibration Procedure for YSI Model 30:

Conductivity meters should be calibrated annually on primary NIST traceable standards.

1. Turn on the meter and rinse the probe in distilled or deionized water.
2. Rinse the probe with the primary conductivity standard solution.
3. Pour about 200 mL of primary standard solution into a clean beaker and immerse the probe. Make sure the temperature and conductivity sensors are fully submerged (i.e. the oval vent hole is submerged).
4. Depress the MODE button until the "°C" is flashing in the lower right portion of the display. The meter is now in temperature compensating mode.
5. Agitate the probe vertically in the solution to dislodge air bubbles from the electrode compartment, but do not allow probe to contact the walls of the container.
6. Allow the temperature to stabilize and record the solution's temperature.
7. Depress the "up" and "down" arrow keys simultaneously.
8. Adjust the reading with the individual "up" and "down" arrow keys to match the value of the primary standard.
9. Save the calibration by depressing the "enter" button.
10. Record in the instrument log book:
    a. the date and operator of the calibration
    b. the purpose of the calibration
11. Rinse the probe thoroughly with deionized water, making sure to direct the rinse water into the electrode ports.

Annual Temperature Probe and Temperature Compensation Check for YSI Model 30:

1. Set up five water baths in five separate coolers, at approximately 5, 10, 15, 20 and 25 °C. Adjust temperatures with ice and warm water as necessary. Make sure all ice is melted and that temperatures of the baths are stable.
2. In the 25 and 5 °C coolers, place two tall glass containers and fill with fresh secondary standards at approximate concentrations of 147 and 1410 µmhos/cm.
3. Let the temperatures of the standards in the glass containers equilibrate with the temperature of the water baths.
4. In the instrument log book, record the temperature of each standard in the 25 and 5°C coolers with an NIST thermometer (not the thermometer on the conductivity meter).
5. Make sure the conductivity meter is in temperature compensation mode.
6. Record the temperature and conductance of each standard at 25 °C and 5° C and only temperature in the 10, 15, and 20 °C coolers with the conductivity meter.
7. Temperatures recorded with the conductivity meter should be within 0.5 °C of the NIST recorded temperature and conductance readings should be within 7% of the standards.
8. If temperatures are not within 0.5 °C of the NIST recorded temperature, return the meter to YSI for servicing.
9. If the recorded conductance is not within 7% of the standards' values, follow the steps in the Troubleshooting and Calibration sections and repeat test.

Methods

Field Procedure for YSI Model 30:

1. At the beginning of the day, follow the accuracy checking procedure steps 1 through 11.
2. If measuring fresh water conductivity, make sure the probe is reading in units of µmhos/cm and that the meter is in temperature compensation mode (flashing "°C" in the lower right portion of the display).
3. If measuring marine water salinity, depress the MODE button until the display shows units of parts per thousand (ppt). NOTE: The YSI Model 30 incorrectly displays the units of parts-per-thousand as “ppt”. Record results with units of “ppth” to ensure proper representation in LIMS and LASAR.
4. Place the conductivity probe into enough sample water to immerse the entire probe (i.e. the oval vent hole is submerged).
5. Agitate the probe vertically in the solution to dislodge air bubbles from the electrode compartment, but do not allow probe to contact the walls of the container.
6. Allow the temperature to stabilize. If the temperature is below 2°C, depress the mode button until the "°C" no longer flashes. The meter is now in non-temperature compensating mode.
7. Record the temperature of the sample to the nearest 0.1 °C.
8. Record the specific conductance or calculate the specific conductance for samples below 2°C ((see Calculations and Data Reporting, below). Record salinity, if applicable.

9. Rinse the probe thoroughly with deionized water, making sure to direct the rinse water into the electrode ports.

Field Procedure for YSI Model 33:

1. At the beginning of the day, follow the accuracy checking procedures.
2. Rinse the probe in distilled or deionized water.
3. Turn the meter selector knob to TEMPERATURE and read the temperature of the solution on the bottom of the scale.
4. Agitate the probe vertically in the solution to dislodge air bubbles from the electrode compartment, but do not allow probe to contact the walls of the container.
5. If reading salinity measurements, adjust the temperature knob in the upper right portion of the meter face to the measured temperature of the sample.
6. Adjust the meter to read at the lowest possible scale with the adjustment knob at the lower right of the meter's face (e.g. x1, x10, x100, or salinity).
7. Correct the conductivity reading for temperature by using the temperature correction table in the front of the logbook.
8. Record the specific conductance or salinity of the sample.

Calculations and Data Reporting

Record the measurements to two significant figures or to the nearest whole number, whichever is less.

To manually calculate the specific conductance, multiply the measured conductivity by the correction factor corresponding to the sample's temperature. A table of the temperature correction factors is located in the front of the meter books.

References

American Public Health Association, American Water Works Association, and Water Environment Federation, 1998. Standard Methods for the Examination of Water and Wastewater (20th Edition), section 2510. American Public Health Association, Washington, DC.

DISSOLVED OXYGEN BY WINKLER TITRATION

Background

Dissolved oxygen (DO) is one of the principal parameters used to measure water quality. Water quality standards have been developed for DO based on the life history requirements of aquatic species, particularly salmonids. Dissolved oxygen (DO) is of fundamental importance for all chemical, biochemical, and biological processes taking place in water. The majority of aquatic processes are aerobic (oxygen is present). When DO is lacking, anaerobic processes take place, which result in the formation of reduced compounds such as methane (CH_4), hydrogen sulfide (H_2S), and ammonia (NH_3). The amount of oxygen that will dissolve in water is dependent upon temperature, altitude and salinity, and these factors must be considered when calculating a sample's percent DO saturation.

DO is usually measured in milligrams per liter (mg/L). Water can hold more dissolved oxygen (DO saturation) at low temperatures than at high temperatures. For example, at 10°C, 100% DO saturation is 11.3 mg/L; at 30°C the same water sample would contain only 7.6 mg/L. DO measurements are made on a variety of samples including surface water, groundwater, landfill and industrial and municipal wastewater, and mixing zones. Concentrations range from less than 0.1 mg/L to greater than 20 mg/L.

In waters supporting salmonids, the necessary DO levels range from 11 mg/L in spawning and rearing waters (in order to support embryo and larval production stages with no impairment) to 6 mg/L in non-spawning waters (the minimum to avoid acute mortality).

Various supplies and demands influence the concentration of DO in water. The primary *sources* for dissolved oxygen are photosynthetic activities of aquatic plants and reaeration (as water spills and splashes downstream, atmospheric oxygen is trapped and dissolved in the water). The major *demands* on DO concentration come from plant respiration and the biological breakdown (or decomposition) of organic material by bacteria and other microorganisms.

Most daily cycles in DO occur as a result of the photosynthesis of aquatic plants. The chemical reaction governing changes in DO related to photosynthesis is (Equation 1):

$$6CO_2 + 12H_2O \xrightarrow{\text{light}} C_6(H_2O)_6 + 6O_2 + 6H_2O \qquad (1)$$

In photosynthesis, carbon dioxide and water are converted, using the sun's energy, to glucose and oxygen. During daylight hours, sunlight is absorbed by chlorophyll. The energy obtained is used to convert carbon dioxide into glucose. Oxygen is formed as a byproduct. Consequently, water becomes more saturated with DO during the day and usually peaks in mid-to-late afternoon. Virtually all aquatic organisms produce carbon dioxide (acid) through their normal metabolism of food (respiration, Equation 2).

$$C_6(H_2O)_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy} \qquad (2)$$

During respiration, metabolic energy is released by converting glucose into carbon dioxide and water, using up roughly the same amount of oxygen originally liberated. As a result, water becomes less saturated with DO during the night and usually is lowest just before sunrise. A similar daily pattern occurs in pH because of photosynthesis, i.e., high during the day and lower at night (see pH section).

Measurement Concepts

Dissolved oxygen is determined in the field using the Azide modification of the Winkler titration (American Public Health Association, et al., 1998, section 4500 O-C). This method is preferable

over use of membrane electrodes (also referred to as DO probes) because of higher precision and accuracy. Membrane electrodes are used to determine DO with continuous monitoring equipment. Please see the continuous monitoring section for more information.

The Winkler Azide modification is an iodometric (titration of iodine) procedure. It is based on the addition of divalent manganese solution ($Mn^{(+2)}SO_4$), followed by strong alkali azide solution (50% NaOH, 15% KI, 1% NaN_3 with the remainder as water), to the sample in a glass-stoppered bottle (Equation 3).

$$MnSO_4 + 2NaOH \rightleftharpoons Mn(OH)_2 + Na_2SO_4 \qquad (3)$$

DO rapidly oxidizes an equivalent amount of divalent (+2) manganese to form the higher valence manganese$^{(+4)}$ hydroxide flocculent (Equation 4).

$$O_2 + 2Mn(OH)_2 \rightleftharpoons 2MnO(OH)_2 \qquad (4)$$

In the presence of iodide ions (from KI in the alkali azide solution) in an acidic solution (H_2SO_4), the oxidized manganese reverts to the divalent state, with the liberation of iodine equivalent to the original DO content (Equations 5 and 6).

$$MnO(OH)_2 + 2H_2SO_4 \rightleftharpoons Mn(SO_4)_2 + 3H_2O \qquad (5)$$

$$Mn(SO_4)_2 + 2KI \rightleftharpoons MnSO_4 + K_2SO_4 + I_2 \qquad (6)$$

Azide ion (N_3^-) is added in the alkali azide solution to suppress interference of nitrite ion with free iodine. The iodine is then titrated with a standard solution of sodium thiosulfate. The amount of thiosulfate used to reach the endpoint is equivalent to the amount of free iodine in solution, which is equivalent to the amount of oxygen present in the sample.

Starch is used as an indicator for iodine (I_2). In a solution with no other colored species, it is possible to see the color of about 5×10^{-6} M I_2. With a starch indicator, the limit of detection is extended by about a factor of ten. The active fraction of starch is amylose, a polymer of the sugar α-D-glucose. The polymer exists as a coiled helix into which small molecules can fit. In the presence of starch and I^-, iodine molecules form long chains of I_5^- ions $[I\text{-}I\text{-}I\text{-}I\text{-}I]^-$ that occupy the center of the amylose helix. It is a visible absorption band of this I_5^- chain, bound within the helix, which gives rise to the characteristic bluish starch-iodine color. During titration of the I_2 with sodium thiosulfate, I_2 is present throughout the reaction up to the endpoint. *Starch should not be added to the reaction until immediately before the endpoint* (as detected visually, by the fading of I_2 to a straw-yellow color). Otherwise, some iodine tends to remain bound to starch particles after the endpoint is (prematurely) reached (Harris, 1991).

Equipment

- Graduated cylinders, 100 mL and 500 mL, for sodium thiosulfate standardization.
- Volumetric pipet, 20 mL, for sodium thiosulfate standardization.
- 300-mL capacity glass Biochemical Oxygen Demand (BOD) incubation bottles with ground glass stoppers. Bottles include plastic caps. Avoid using bottles that are chipped around the rim.
- BOD bottle boxes or plastic wire baskets for transporting bottles.
- 250-mL containers for titration reagents. HDPE is suitable for manganous sulfate and alkali-azide solutions; however the alkali-azide container should be amber to prevent light exposure. The sulfuric acid container must be of FEP material.
- 2-mL plunger-type auto-pipettors for delivering titration reagents.
- 200-mL HDPE volumetric flasks modified to contain exactly 203 mL.
- Wide mouth Erlenmeyer flasks, 600 mL.

- Automatic self-zeroing 10-mL acrylic buret with 500-mL squeeze bottle & tubing. Use an opaque bottle or wrap the bottle with opaque tape to protect the solution from light.
- 250-mL Precise-Volume (2 mL) Dispenser (HDPE) for starch.
- Amber glass dropping bottle with dropper for back-titrant.

Supplies

- Manganous sulfate. Prepared by the inorganic section of the laboratory: Dissolve 728 g $MnSO_4 \bullet H_2O$ in distilled H_20 and dilute to 2 liters.
- Alkali-azide reagent. Prepared by the inorganic section of the laboratory: Dissolve 1000 g NaOH and 300 g KI in distilled water, cool, and dilute to 2 liters. Dissolve 20 g NaN_3 in 80 mL distilled water, and add to the alkali solution.
- Sulfuric Acid, concentrated. Purchased reagent grade.
- As an alternative to the three above liquid chemicals, when backpacking chemicals into the monitoring site or there are other situations increasing the risk of exposure from spillage, use the following Hach dry chemical pillows:
    - Manganous sulfate powder pillow
    - Alkali-azide powder pillow
    - Sulfamic acid powder pillow
    - Toenail clippers to open pillows
- Starch indicator. Prepared by the inorganic section of the laboratory: Dissolve 5 g laboratory grade soluble starch in one liter of hot, distilled water. Add 1.25 g salicylic acid as a preservative.
- Standard sodium thiosulfate (0.025 N). Purchased in stabilized form (preferably certified as traceable to NIST) or prepared by the inorganic section of the laboratory: Dissolve 12.409 g $Na_2S_2O_3 \bullet 5H_2O$ in distilled H_20 and dilute to 2 liters. Store in refrigerator in a brown glass (or plastic) bottle.

Expired reagents affect analytical results!

Ensure that reagents, buffers, and standards are not beyond their expiration date (as indicated on the container) or otherwise appear contaminated.

Sodium thiosulfate: Expiration date is six months from the fill date.

All other DO reagents: Expiration date is one year from the fill date.

Spent concentrated acids and bases should be neutralized or diluted and flushed down the

- Potassium bi-iodate (0.1 N) stock solution. Prepared by the inorganic section of the laboratory: Dissolve 3.249 g $KH(IO_3)_2$ in distilled H_2O and dilute to 1 liter.
- Potassium bi-iodate (0.025 N) back-titrant solution. Prepared by the inorganic section of the laboratory: Dilute stock solution 1:4 and store in an amber eyedropper bottle.
- Potassium bi-iodate (0.0250 ± 0.0001N) for sodium thiosulfate standardization - purchased.
- Potassium Iodide (KI), crystals. Purchased, Baker-analyzed.

LABORATORY CHEMICAL SAFETY

Read and familiarize yourself with the Dissolved Oxygen Job Safety Assessment before performing this analysis. See your section safety representative for details.

To minimize the hazards of chemical exposure, handle all chemicals using safety goggles (with elastic band) and PVC gloves. Transfer manganous sulfate, alkali-azide reagent, and concentrated sulfuric acid using auto-pipettor. Transfer other chemicals between containers using a funnel and rinse the funnel after use. Ensure acid neutralizer is available and know how to use the eyewash station.

To minimize chemical spills, handle the chemicals with caution and ensure container lids are tightly fastened. Be cognizant of laboratory safety manual, chemical hygiene plan, and emergency operations plan (especially spill procedures).

To minimize hazards associated with unstable chemical reactions, store alkali-azide reagent and sodium thiosulfate separately from the concentrated sulfuric acid to prevent contact between these chemicals.

Calibration and Standardization

Using the following method, verify the concentration of the 0.025 N sodium thiosulfate standard solution upon opening a new container to prevent the use of degraded reagent. Write results, date, and initials on the bottle label. Perform this test in duplicate and proceed carefully to assure results. The titrant (standard sodium thiosulfate solution) and potassium bi-iodate solution must be accurately measured to verify the concentration of the titrant within 0.1 mg/L.

1. Fill buret with DI water and drain it. Thoroughly rinse buret with sodium thiosulfate titrant to be tested. Fill and zero the buret. Wipe buret tip with a Kimwipe.
2. Fill a clean, glass, 500-mL Erlenmeyer flask with approximately 180 mL distilled water. Add approximately 2 g of KI crystals (one full scoop of the spoon-shaped green spatula) and a few drops of concentrated sulfuric acid. Swirl to mix.
3. Pour about 25 mL of the 0.0250 N potassium bi-iodate standard into a clean, ***dry*** beaker. *Be sure to tightly cap the bottle of standard to prevent evaporation.* Overfill a clean, ***dry,*** 20-mL ***volumetric*** pipet with potassium bi-iodate standard in the beaker. ***Don't pipet directly from the bottle of standard!*** Wipe the lower portion of the pipet with a Kimwipe to remove excess droplets, then drain the pipet until the meniscus is at the 20-mL indicator line. Wipe the excess droplets from the tip and dispense the 20-mL into the Erlenmeyer flask. Use proper technique: Hold the pipet vertically and rest the tip against the wall of the flask. Allow the pipet to drain completely, then wait a few more seconds before removing it from the flask. A small amount of liquid will remain in the tip – ***Do not expel it!***
4. Titrate with the standard sodium thiosulfate. 20 mL will normally be required for standardization. After approximately 18 mL have been added and/or a straw yellow color has been reached, add several drops of starch indicator solution and continue titrating to the endpoint. The endpoint is reached at the first disappearance of any trace of blue color. ***Be careful – no back-titrating allowed!*** The color may reappear upon standing, but do not add any additional titrant.
5. Record the volume of titrant used. A titrant volume of 20.0 mL is equivalent to the expected sodium thiosulfate standard concentration of 0.0250 N. An acceptable titrant

volume is 20.0 ± 0.1 mL. Discard titrant outside of this range. ***Write results, date, and initials on the bottle label.***

6. Thoroughly rinse all glassware with DI water. Drain and store buret in an inverted position in the storage rack.

Methods

Sample Collection Considerations

FIELD SAMPLE COLLECTION AND ANALYSIS SAFETY

Read and familiarize yourself with the Dissolved Oxygen Job Safety Assessment before performing this analysis. See your section safety representative for details.

To prevent obtaining cuts from handling the glass BOD bottles, carefully examine the bottle for chips and cracks prior to handling and use caution. To minimize the hazard of exposure to environmental toxins or pathogens, use PVC gloves when handling samples. Ensure acid neutralizer is available and know how to flush your eyes in the field.

To minimize chemical spills, handle the chemicals with caution and ensure container lids are tightly fastened. Be cognizant of laboratory safety manual, chemical hygiene plan, and emergency operations plan (especially spill procedures).

To minimize hazards associated with unstable chemical reactions, store alkali-azide reagent and sodium thiosulfate separately from the concentrated sulfuric acid to prevent contact between these chemicals.

Collection of samples for DO must be done carefully to avoid introduction of air. Air bubbles in the sample could potentially influence your results. Collect underwater if possible or otherwise fill bottle to overflowing and avoid agitating sample.

Avoid introduction of air into the BOD sample to prevent erroneously low (or even negative) BOD results. If possible, stopper the BOD bottle while it is submerged in the sample (either in the bucket or in the stream). Affix a plastic BOD bottle cap, completely filled with sample water, over the top of the bottle to further prevent the introduction of air.

Blanks and analyses of solutions of known concentration are not applicable to DO measurements, as blank water DO concentration is uncontrollable and solutions of known concentration are not readily available.

Figure DO-1

Figure DO-2

Fig. DO-3

Fig. DO-4

Sample Preparation with Liquid Chemicals

After a DO sample has been collected in a 300-mL glass BOD bottle, the sample is first "fixed" with the three chemical reagents as follows:

1. Remove the glass stopper from the sample bottle and add 2 mL of manganous sulfate using a 2-mL pipettor. Hold the pipet vertically and rest the tip against the neck of the bottle above the sample surface before ejecting the reagent. This will prevent additional aeration of the sample, as well as contamination of the reagent bottle (Figure DO-1)

2. Add 2 mL of alkali-azide reagent to the sample bottle in the same manner.
3. Replace the glass stopper in the sample bottle without trapping air in the bottle. Rinse the top of the bottle to prevent inadvertent splashing of corrosive reagents upon the analyst. Vigorously shake the sample bottle about 30 times (Figure DO-2). Then let the resulting flocculent (floc) settle to no more than half of the bottle height (Figure DO-3).
4. Remove the glass stopper from the sample bottle and add 2 mL of concentrated sulfuric acid to the bottle in the same manner as above.
5. Replace the glass stopper in the sample bottle without trapping air. Rinse the bottle top and shake again as in step 3, until all of the flocculent has dissolved.
6. The sample is "fixed" and ready to be titrated (Figure DO-4). The iodine concentration and thus the measured DO of a sample can change considerably in a short period due to temperature fluctuations, biological activity or exposure to light or air. Analyze samples immediately whenever possible. Otherwise, **store in the dark** at 10-20° during transport. Preserved samples can be held for up to 8 hours prior to final titration (OR DEQ, 1997).

Sample Preparation with Dry Chemicals

When backpacking chemicals into the monitoring site or there are other situations increasing the risk of exposure from spillage, use the Hach dry chemical pillows in the following manner:

1. Add the contents of one manganous sulfate powder pillow and one alkaline iodine-azide powder pillow. Open the powder pillows with toenail clippers.
2. Immediately insert the stopper so air is not trapped in the bottle. Vigorously shake bottle about 30 times to mix. An orange flocculent will form.
3. Wait until the floc has settled to the bottom. This should take a few minutes. Again vigorously shake the bottle about 30 times and wait until the floc has settled.
4. Remove the stopper and add the contents of the sulfamic acid powder pillow. Replace the stopper without trapping air in the bottle and vigorously shake the bottle about 30 times to mix. The floc will dissolve and leave a yellow color if oxygen is present.
5. The sample is "fixed" and ready to be titrated. Analyze samples immediately whenever possible. Otherwise, **store in the dark** at 10-20° during transport. If far afield, cap the bottle with a water seal and secure the seal with duct tape, place the bottles in the black nylon bag, and place the bag in a shaded spot in the stream. Preserved samples can be held for up to 8 hours prior to final titration (OR DEQ, 1997).

Sample titration

NOTE: Prior to the first DO titration of the day, drain and refill the automatic buret containing the sodium thiosulfate to ensure no bubbles remain in the buret tip. This prevents the use of titrant that may have degraded due to light exposure. Examine the buret and tubing. Replace the tubing if it is dirty or cracked. Dirty burets can cause as much as 0.1 mL of titrant to adhere to the buret wall. Replace dirty burets or return to the lab for a cleaning with an alcoholic-KOH solution so that the buret drains smoothly and the meniscus is satisfactory.

1. Measure out 203 mL of sample and pour into a 600-mL Erlenmeyer flask. Use a Nalgene 200-mL volumetric flask that has been modified to hold exactly 203 mL, and has a rubber stopper fitted over the end of the neck of the flask. Invert the volumetric flask over the top of the sample bottle (Figure DO-5). Hold the flask tightly against the top of the sample bottle and invert so that the volumetric flask is below the sample bottle (Figure DO-6). Allow the volumetric flask to fill completely. Remove the glass sample bottle

from the top of the volumetric flask, spilling as little liquid as possible. Then pour the contents of the volumetric flask into the 600-mL Erlenmeyer flask (Figure DO-7).

Figure DO-5

Figure DO-6

Figure DO-7

2. Place the Erlenmeyer flask under the graduated 10-mL automatic buret filled with sodium thiosulfate (Figure 8). Open the stopcock of the buret and titrate the sample to a straw yellow color (Figure 9), then close the buret stopcock. Add several drops of starch indicator solution to the sample. The starch will change the sample color from straw yellow to blue (Figure 10). Open the buret stopcock again and carefully continue titrating to the endpoint (Figure 11). The endpoint is reached at the first disappearance of any trace of blue color (Figure 12). If 10.0 mL (and subsequent increments of 10 mL) of titrant is used before the endpoint is reached, refill the buret with sodium thiosulfate, note the volume used, and continue the titration.

NOTE: Colored or turbid samples may be difficult to titrate because of interference with the visual detection of the endpoint. Add titrant slowly and add the starch sooner than usual.

3. After the endpoint has been reached, add one to two drops of 0.025 N potassium bi-iodate

Fig. 8

Fig. 9

Fig. 10

Fig. 11

Fig. 12

Fig. 13

back-titrant solution. If the blue color reappears, the endpoint was successfully reached (Figure 13). If the blue color does not reappear, back-titrate with 0.025 N potassium bi-iodate drop-wise until the blue color reappears. Two drops are equivalent to 0.1 mL of sodium thiosulfate titrant.

4. Empty the waste into a waste carboy, which will be transported to the laboratory for disposal. Rinse
5. the Erlenmeyer flask with distilled water. Wipe down the benchtop to maintain a clean, white surface to detect the titration endpoint.

Repeating titrations: If a titration needs to be rechecked, measure the volume remaining in the glass DO sample bottle using a 100 mL graduated cylinder and pour into an Erlenmeyer flask. Titrate to the endpoint as described above.

Calculations and Data Reporting

DO Concentration

Note the volume of titrant used, taking into account both the starting level in the buret and the equivalent amount of back-titrant used (in the event that the endpoint was overshot). The DO concentration (mg/L) is equivalent to the volume (mL) of titrant. Winkler titration is precise to ± 0.1 mg/L. Record the resultant concentration to the nearest 0.1 mg/L on the field data sheet.

Repeating titrations: In the event of a repeat titration, read the volume of sodium thiosulfate used to reach the endpoint and calculate the concentration of DO in mg/L as follows (Equation 7):

$$\text{DO (mg/L)} = \text{titrant volume} \times (203/\text{sample volume}) \qquad (7)$$

Record the resultant DO to the nearest 0.1 mg/L on the field data sheet and note the sample volume used for the repeat titration on the datasheet.

DO Saturation

The calculation from DO concentration to DO saturation involves corrections for sample temperature, site elevation, and sample salinity. All correction factors are available on the "DEQ Laboratory Percent Saturation Calculation Sheet" (Table DO-1).

Correction for Sample Temperature

Determine DO and temperature (C) of the sample. Use the Percent Saturation Table (in Table DO-1) to determine the 100% DO saturation level at the temperature that was measured. Divide the sample DO by the table DO and multiply the result by 100.

Correction for Elevation

If the sample site is more than 500 feet above sea level, find the closest elevation to your site in the Elevation Correction Table (in Table DO-1). Multiply the factor for that elevation by the result obtained from the correction for sample temperature.

Percent Saturation Table				Elevation Correction		Salinity Correction			
Water Temperature C	DO 100% Saturation	Water Temperature C	DO 100% Saturation	Elevation in feet	Elevation Factor	Salinity (ppth)	Salinity Factor	Salinity (ppth)	Salinity Factor
0.0	14.60	20.5	9.10	0	1.00	0.0	1.00	20.5	1.15
0.5	14.40	21.0	9.00	500	1.02	0.5	1.00	21.0	1.15
1.0	14.20	21.5	8.90	750	1.03	1.0	1.01	21.5	1.16
1.5	14.00	22.0	8.80	1000	1.04	1.5	1.01	22.0	1.16
2.0	13.80	22.5	8.75	1250	1.05	2.0	1.01	22.5	1.17
2.5	13.65	23.0	8.70	1500	1.05	2.5	1.02	23.0	1.17
3.0	13.50	23.5	8.60	1750	1.06	3.0	1.02	23.5	1.17
3.5	13.30	24.0	8.50	2000	1.07	3.5	1.03	24.0	1.18
4.0	13.10	24.5	8.45	2250	1.08	4.0	1.03	24.5	1.18
4.5	12.95	25.0	8.40	2500	1.09	4.5	1.03	25.0	1.19
5.0	12.80	25.5	8.30	2750	1.10	5.0	1.04	25.5	1.19
5.5	12.65	26.0	8.20	3000	1.11	5.5	1.04	26.0	1.19
6.0	12.50	26.5	8.15	3250	1.12	6.0	1.04	26.5	1.20
6.5	12.35	27.0	8.10	3500	1.13	6.5	1.05	27.0	1.20
7.0	12.20	27.5	8.00	3750	1.14	7.0	1.05	27.5	1.20
7.5	12.05	28.0	7.90	4000	1.15	7.5	1.05	28.0	1.21
8.0	11.90	28.5	7.85	4250	1.16	8.0	1.06	28.5	1.21
8.5	11.75	29.0	7.80	4500	1.17	8.5	1.06	29.0	1.22
9.0	11.60	29.5	7.70	4750	1.19	9.0	1.07	29.5	1.22
9.5	11.45	30.0	7.60	5000	1.20	9.5	1.07	30.0	1.23
10.0	11.30	30.5	7.55	5250	1.21	10.0	1.07	30.5	1.23
10.5	11.20	31.0	7.50	5500	1.22	10.5	1.08	31.0	1.23
11.0	11.10	31.5	7.45	5750	1.23	11.0	1.08	31.5	1.24
11.5	10.95	32.0	7.40	6000	1.24	11.5	1.08	32.0	1.24
12.0	10.80	32.5	7.35	6250	1.25	12.0	1.09	32.5	1.25
12.5	10.70	33.0	7.30	6500	1.26	12.5	1.09	33.0	1.25
13.0	10.60	33.5	7.25	6750	1.27	13.0	1.09	33.5	1.25
13.5	10.50	34.0	7.20	7000	1.29	13.5	1.10	34.0	1.26
14.0	10.40	34.5	7.15	7250	1.30	14.0	1.10	34.5	1.26
14.5	10.30	35.0	7.10	7500	1.31	14.5	1.11	35.0	1.27
15.0	10.20	35.5	7.05	7750	1.32	15.0	1.11	35.5	1.27
15.5	10.10			8000	1.34	15.5	1.11	36.0	1.28
16.0	10.00					16.0	1.12	36.5	1.28
16.5	9.85					16.5	1.12	37.0	1.29
17.0	9.70					17.0	1.12	37.5	1.29
17.5	9.60					17.5	1.13	38.0	1.29
18.0	9.50					18.0	1.13	38.5	1.30
18.5	9.45					18.5	1.14	39.0	1.30
19.0	9.40					19.0	1.14	39.5	1.31
19.5	9.30					19.5	1.14	40.0	1.31
20.0	9.20					20.0	1.15		

Table DO-1. Dissolved Oxygen Percent Saturation Calculation Sheet

Correction for Sample Salinity

If the sample salinity is greater than or equal to 1.0 part per thousand (ppth), then find the salinity factor in the Salinity Correction Table (in Table DO-1). Multiply the factor for that salinity by the result obtained from the first two steps.

Mathematical Representation (EQUATION 8).

$$DO_{Sat} = (DO_{Conc} / DO_{100}) * f_E * f_S * 100 \quad (8)$$

Where

DO_{Sat}	=	DO Percent Saturation (%),
DO_{Conc}	=	DO Concentration (mg/L),
DO_{100}	=	100% Saturation at Sample Temperature,
f_E	=	Correction for Elevation (if site elevation > 500 feet), and
f_S	=	Correction for Salinity (if salinity > 1.0 ppth).

DO saturation calculations are precise to 0.7 – 1.4 %. Report results to the nearest whole percentage.

References

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TURBIDITY

Background

Turbidity is an expression of optical properties of a fluid that causes light to be scattered or absorbed. Suspended matter, such as clay, silt, fine organic and inorganic matter, soluble colored organic compounds, plankton and other microscopic organisms contribute to the turbidity of natural waters.

Equipment and Supplies

Turbidity is measured in the field with a portable turbidimeter. The Hach 2100P portable turbidimeter operates on the nephelometric principle of turbidity measurement. A tungsten-filament lamp projects light through a sample cell to a transmittance light detector. Light scattered by particles suspended in the sample is monitored by a second detector positioned 90^{o} to the path of transmitted light. A microprocessor calculates the ratio of signal from the 90^{o} and transmitted light detectors. This technique corrects for color and light absorbing materials and compensates for fluctuations in light intensity. Turbidity measured in this way is reported in nephelometric turbidity units or NTU.

For information about the meter, contact:

The HACH Company

PO Box 608

Loveland, CO 80539-0608

1-800-227-4224

Calibration and Standardization

Hach 2100P turbidimeters require calibration on a quarterly basis using Hach StablCal formazin suspensions. Calibrate the meter using four formazin suspensions of less than 0.1, 20, 100 and 800 NTU following instructions in the Hach manual. To ensure accuracy, calibration of the turbidimeter should occur in the laboratory rather than the field environment.

Gelex secondary standards are particulate suspensions with light scattering characteristics similar to the formazin primary standards. These Gelex secondary standards are used to determine turbidimeter accuracy in the field. New values are assigned to the Gelex secondary standards at the time of meter calibration. These secondary standards range from 0-10, 0-100, and 0-1000 NTU. Each meter requires a unique set of Gelex secondary standards and the value assigned to the Gelex secondary standards is determined against formazin in the same instrument that will be used with field calibration checks.

To assign new values to the Gelex secondary standards after meter calibration, first clean and apply silicone oil to a sample cell as directed in section 2 of the Hach manual. Insert each secondary standard cell into the turbidimeter and read the turbidity value. Record this value on a label affixed to the cap of the sample cell or on the white diamond on the cell itself. Do not store or expose the Gelex secondary standards to extreme temperatures (below 0°C or above 50°C) or they may be damaged.

Check the turbidimeter at the beginning and end of the day with the Gelex secondary standards.

Documentation Record calibration activities, Gelex secondary standard assignment values, lab checks and field checks in the turbidimeter log book. Keep this logbook current as part of the quality assurance record.

Methods

Sample Collection

Clay, silts and other fine materials that cause turbidity are generally well mixed and distributed throughout the water column. A sample collected midstream is usually representative of the stream reach and acceptable for ambient monitoring purposes.

Suitable sample containers include stainless steel buckets, polyethylene bottles or other clean containers. Fully immerse and fill the sample container. A sample depth of one meter is standard for larger streams. Minimize disturbance of streambed and banks to avoid possible contamination of the sample.

Sample Preservation

Turbidity measurements should be made immediately after sample collection as light, temperature, and other processes can affect turbidity over time. If necessary samples may be held for 48 hours before analysis, however in such circumstances samples should be stored at 4°C (in ice or refrigerated) and held in darkness.

Measurement

Inspect the turbidimeter logbook to ensure that the instrument has been calibrated to formazin standards within the last quarter. Check the turbidimeter to ensure it is operating properly before measuring the first turbidity sample. Measurements are made with the turbidimeter set in automatic range mode (AUTO RNG) with the signal averaging (SIG AVG) mode off.

Compare the assigned values of the Gelex secondary standards with the observed values. Calibration of the turbidimeter with formazin standards is necessary if the reading of the Gelex secondary standard is not within 5% of the assigned value. Conduct a field check of the meter using the Gelex secondary standards each day before samples are analyzed.

Clean and apply silicone oil to a sample cell as directed in section 2 of the Hach manual.

Agitate the primary sample container (e.g. sample bucket or HDPE bottle) to re-suspend material that may have settled between the time of sample collection and analysis, but avoid causing bubbles to form. Degassing the sample is not necessary for most ambient water monitoring applications. Fill the glass sample cell with 15 mL of sample, cap and wipe dry and clean. Holding the sample cell by the cap, carefully align the diamond on the sample cell with the line on the turbidimeter and place the sample cell into the turbidimeter. Press “Read” to measure turbidity.

A single sample cell should be used through the course of the day for the best precision and repeatability. Each sample cell will gradually become slightly scratched and abraded through use and these imperfections may affect the optical properties of the sample cell. Slight imperfections in the sample cell are masked by the application of silicone oil, but visibly scratched cells may result in erroneous results and should be discarded. Condensate, incorrect sample cell alignment, or use of the meter in direct sunlight may also produce inaccurate turbidity values.

QC measures Collect duplicate samples at least once a day or at 10% of the sites, whichever is greater. Equipment blank measurements are made using distilled water.

Calculations and Data Reporting

Read and record the turbidity value to the nearest two significant digits (for example, 123 NTU is reported as 120 NTU). An exception to this rule is when turbidity is less than 10 NTU, in which case record to the nearest unit (for example, 8.6 NTU is reported as 9 NTU). The minimum reporting limit is 1 NTU; any reading less than 1 NTU is reported as <1. Remember to round to even. If the fraction is greater than ½, round up. If the fraction is less than ½, round down. If the fraction equals ½, round to the nearest even number. See Chapter 2 Data Management Section for a discussion on rounding error.

References

Hach, 1997. Hach Portable Turbidimeter Model 2100P Instrument and Procedure Manual, 8-25-94-6ED, Rev. 5. Hach Company, Loveland, Colorado.

E. COLI

Background

Escherichia coli (*E. coli*) bacteria are indicator organisms; that is they are monitored in surface waters because their presence indicates fecal contamination is present. Because it is not practical or feasible to test for all the disease-causing organisms that can be present in surface water, we use *E. coli* as an indicator because it is commonly found in human and animal wastes and is easy to quantify in the laboratory. If *E. coli* is present above certain levels, then other disease-causing organisms may be present and a potential threat to human health exists.

Over the years the choice of indicator organism used in water quality standards has changed as new studies are performed to determine which indicator correlates best with human illness. The 1992-1994 Triennial Water Quality Standards Review recommended that *E. coli* replace enterococci as the indicator for freshwater and estuarine/non-shellfish producing waters and that fecal coliform be retained as the indicator for marine/shellfish producing waters.

The U.S. Environmental Protection Agency (EPA) approved test methods for detection of *E. coli* and enterococcus in fresh ambient water matrices and enterococcus in marine ambient water matrices (in Federal Register, 2003). This protocol explains the methods for sample collection and use of the Quanti-Tray® and Quanti-Tray 2000® MPN (most probable number) Enumeration Test Procedure and Colilert Reagent, both patented by IDEXX Laboratories, Inc. These methods are among those approved by EPA. The substrate used in the test contains two indicator compounds (ONPG and MUG) that either produce a color or fluoresce when metabolized by total coliform or *E. coli*, respectively. This method is easy to use, provides results in 24 hours, and compares favorably with other methods for quantifying *E. coli*. The IDEXX Quanti-Tray 2000® MPN Method has a maximum counting range of 2,419 E. coli per 100 mL on undiluted samples. The maximum counting range of the Quanti-Tray® MPN Method is 200 MPN/100 mL on undiluted samples. As with other bacterial enumeration methods, the counting range can be extended by serial sample dilution. The Quanti-Tray 2000® method is recommended for environmental water samples because the 200 MPN/100 mL maximum quantification of the Quanti-Tray® method is less than the state *E. coli* standard of 406 MPN/100 mL.

Colilert®-18 reagent produces results after 18, rather than 24, hours of incubation, and can be used on either fresh or marine water samples. Marine samples may only be analyzed with Colilert®-18 reagent, not with Colilert®-24 reagent. Colilert®-18 reagent takes into account higher salinity and interference from the fibrio organism. Marine samples must be diluted at least ten-fold before analysis with Colilert®-18.

In brief, a water sample is mixed with the Colilert reagent and divided up into a series of wells. After incubation at the optimal temperature the number of positive wells is recorded (the number which turns yellow indicates total coliform and the number which fluoresce under 365 nanometer (nm) ultraviolet (UV) light indicates *E. coli*). The number of positive wells depends on the bacterial concentration in the original sample. The actual bacterial concentration is read from an MPN table based on the principle that each well has a certain probability of being positive.

Equipment and Supplies

All of the equipment and supplies can be ordered directly from IDEXX Laboratories, Inc. at telephone number 1-800-321-0207.

Item	Catalog Number
Colilert® reagent packs for 100 mL samples (20-Pack or 200-Pack)	WP020
Colilert®-18 reagent packs for 100 mL samples (20-Pack or 200-Pack)	WP020-18
Quanti-Tray Sealer (110 Volt)	WQTS-110
Quanti-Tray Sealer (220 Volt)	WQTS-220
Quanti-Tray/2000®	WQT2K-100 (100 trays)
Quanti-Tray®	WQT-100 (100 trays)
97-Well Rubber Insert	WQT RBR-2K (use with Sealer)
Colilert Comparator with Vessel	WP104
Collection Bottles with thiosulfate, 120 mL (20 per case or 200 per case)	WV120SBST-20
Quanti-Cult® QC Kit {Quality Control Bacteria (3 sets)}	WKIT-1001
Incubator, 35°C (110 Volt/60Hz)	WI300
Incubator, 35°C (220 Volt/50Hz)	WI3001
UV Viewing Cabinet	WCM10
Fluorescent UV Lamp, 365nm	WL160 (110V AC cord)
Or other 365 nm long wave UV lamp	WEA160F (220V European cord)
UV Absorbing Safety Goggles	WLG
UV Absorbing Safety Spectacles	WLS

Calibration and Standardization

This equipment need not be calibrated, although the incubator temperature must be maintained within 0.5°C of 35C° during incubation. Dry incubators may need to be turned on at least 12 hours before use to ensure that the temperature is stable. The incubator temperature should be checked and recorded daily during periods of use.

For each batch of Colilert® reagent (check Lot Number on package), follow the quality control procedure provided with the Quanti-Cult® QC Kit. This involves inoculating three separate bottles containing 100 mL of sterile water with three different bacteria cultures and following the test procedure explained in the Methods section. The following results should be obtained: *E. coli*--yellow, fluorescent; *Klebsiella pneumoniae*--yellow, not fluorescent; *Pseudomonas aeruginosa* (non-coliform negative control)--clear, not fluorescent.

Methods

Holding Time: After collecting the sample, the method allows 6 hours to deliver samples to the lab. Upon receipt, the samples must be refrigerated and processed within 2 hours.

Refer to the instructions that accompany the reagents and equipment.

1. Remove the lid from a 120 mL clean, sterile bottle without touching the bottle neck or cap threads. The bottle should have a 100 mL fill line like the IDEXX Collection Bottles listed in the equipment and supply list, and adequate volume to allow for vigorous mixing of the sample. For chlorinated water, use sample containers containing sodium thiosulfate so that chlorine will be neutralized.
2. After collecting sample, pour out excess sample so that the final volume is approximately 100 mL. Tightly cap the bottle and shake to dissolve the sodium thiosulfate, if present. If the sample was collected in a Whirl-Pak bag or a larger sterile container, transfer 100 mL into a clean, sterile bottle. Sample transfer should be done in the laboratory or mobile unit with a pipette for sterile transfer.
3. If the sample *E. coli* concentration is likely to exceed an MPN of 2,419 per 100 mL (200 MPN/100 mL for Quanti-Tray®) **or if the sample is saline**, the sample should be diluted with sterile distilled water. Use an aseptic pipette to transfer a portion of sample into a prepared sterile dilution water blank. For example, a ten-fold dilution is accomplished by transferring with a pipette 10 mL of sample into 90 mL of water. The diluted sample is then capped, shaken vigorously, and treated like a regular sample.
4. Carefully separate one Snap Pack of Colilert® or Colilert®-18 (for saline water) reagent from the strip. Tap it so that all of the powder is on the bottom of the pack.
5. Open the Snap Pack by snapping back the top at the line. Do not touch the opening.
6. Add the reagent to the 100 mL water sample (Figure Ec-1).
7. Cap the sample jar tightly without touching the bottle neck or cap threads.
8. Shake the sample vigorously until the reagent powder is dissolved.
9. Allow sample to sit undisturbed for a few minutes to reduce foaming.
10. Open the Quanti-Tray or Quanti-Tray/2000® and hold it in one hand in a U-shape as you pour the entire sample into it, touching only the foil tab (Figure Ec-2). Tap the small wells two to three times to eliminate air bubbles.

Figure Ec-1

Figure Ec-2

Figure Ec-3

11. Follow the manufacturer instructions to send the sample tray in the insert through the sealing machine (Figure Ec-3).
12. Incubate the tray filled with sample for 24 hours (with Colilert®) or 18 hours (with Colilert®-18) at 35+/-0.5°C. Do not overload incubators or water baths with sample trays because samples will not achieve proper incubation temperature. The IDEXX incubator holds a maximum of 12 trays, six on the bottom and six on the shelf.
13. Comparator is a liquid which contains the minimum yellow color and fluorescence representing a positive result. Prepare the comparator sample by aseptically transferring the comparator from the glass bottle to a sterile Quanti-Tray® or Quanti-Tray/2000® and sending it through the sealing machine. Record the lot number and expiration date of the comparator on the tray. Store the comparator sample in the dark between 4 and 30°C when not in use.
14. After 18 (for Colilert®-18) or 24 (for Colilert®) hours of incubation, read and record the results of the test.
    - If the wells in the Quanti-Tray® or Quanti-Tray/2000® do not have a yellow color, the test is negative.
    - If the wells are yellow but a lighter yellow than the comparator, the tray may be incubated an additional four hours (no longer than 22 or 28 hours total, respectively, for Colilert®-18 and Colilert®) and reexamined. If they are still lighter yellow than the comparator after an additional four hours of incubation, the test is negative.
    - Wells that have turned as yellow as the comparator indicate the presence of total coliform bacteria (Figure Ec-4).

Figure Ec-4

15. If the wells are at least as yellow as the comparator, check each well for fluorescence (Figure Ec-5) by placing a 6 watt 365 nm UV light within five inches of the sample in a dark place. For convenience and safety, use the IDEXX viewing cabinet. If a cabinet is not available, use UV protective eyewear.

Figure Ec-5: Fluorescent sample (positive E. coli), negative sample, and yellow sample (positive total coliform).

16. If using the Quanti-Tray/2000®, read and record the number of small wells that fluoresce and separately record the number of large wells that fluoresce, including the large well at the top of the tray.
17. If using the Quanti-Tray®, read and record the number of wells that fluoresce, including the large well at the top of the tray.

LABORATORY CHEMICAL SAFETY

Ultraviolet (UV) light damages the human eye. Wear UV eye protection if viewing the sample with the light outside of a dark, enclosed box.

If comparator comes in contact with eyes or skin, flush thoroughly with water.

QUANTI-CULT contains live microorganisms and should be used only by individuals with bacteriological training. Properly disinfect any spills and sterilize all used containers according to appropriate regulations before disposal. Be cognizant of laboratory safety manual, chemical hygiene plan, and emergency operations plan (especially spill procedures).

Calculations and Data Reporting

Refer to the MPN table provided with the Quanti-Tray® or Quanti-Tray/2000® to obtain the Most Probable Number (MPN) of *E. coli* in the sample.

If the sample was diluted, multiply the result by the appropriate dilution factor.

If all the wells in the tray are positive, the results must be reported as >2,419 MPN/100 mL (Quanti-Tray/2000®) or >200 MPN/100 mL (Quanti-Tray®).

Any remaining sample, if it has been stored at 4°C, may be diluted, prepared, and placed in the incubator within up to 8 hours (6 hours to deliver samples to the lab, refrigerate samples upon receipt, and process within 2 hours) of collection. If incubation begins later than this, any results must be reported as estimates.

References

American Public Health Association, American Water Works Association, and Water Environment Federation, 1999. Standard Methods for the Examination of Water and Wastewater (20th Edition), section 9223. American Public Health Association, Washington, DC.

Federal Register, 2003. Part III, Environmental Protection Agency, 40 CFR Part 136, Guidelines Establishing Test Procedures for the Analysis of Pollutants; Analytical Methods for Biological Pollutants in Ambient Water; Final Rule. Federal Register / Vol. 68, No. 139 / Monday, July 21, 2003 / Rules and Regulations, 43272-43283, Washington, DC.

FLOW MEASUREMENT

Background

These protocols are based on methods used by the United States Geological Survey and the Oregon Water Resources Department. A narrated CD-ROM produced by the USGS (see references) provides detailed instruction for making wading flow measurements.

These protocols cover both wading and bridge-based measurements. For wading measurements the flow meter is attached to a top-setting wading rod, whereas bridge based measurements suspend the flow meter with a cable and sounding weight. In either case, discharge (flow) is calculated using the velocity-area method (Equation 1):

Discharge = (area of water in a cross-section * mean water velocity) (1)

In order to calculate discharge, the stream cross-section is divided into numerous subsections to characterize the cross-section geometry. The area of each subsection is determined by measuring the width and depth. Water velocity in each subsection is measured using a flow meter.

Personal safety is the foremost consideration when making discharge measurements. Two staff persons should be present for all discharge measurements. For wading measurements, staff must wear felt soled or cleated waders, and must not attempt to wade in channels where water depth, velocity, or submerged or floating debris pose a risk to personal safety. When wading, proceed carefully and use the wading rod to probe the streambed ahead of you.

Likewise, staff must assess safety conditions such as traffic patterns, walkways, railings, and bridge superstructure when planning to make discharge measurements from bridges. One must keep hands and fingers clear of the winch gears and cable to avoid possible injury or dismemberment if a sounding weight was accidentally caused to free-fall. *This type of accident could easily occur on winches equipped with a clutch mechanism, so this warning should not be taken lightly*. Care must also be exercised when lifting heavy sounding weights over bridge railings and transporting weights to and from the bridge site. The best way to transport weights on site is to place them in the bridge crane's weight holder (if so equipped). Steel-toe shoes are recommended when working with sounding weights.

The DEQ owns a variety of flow meters / flow calculators including Marsh-McBirney, Swoffer, JBS AquaCalc, Price Pygmy, and Price AA. This protocol covers the mechanics of making a discharge measurement with a properly functioning flow meter --it is the staff person's responsibility to read instrument manuals and be familiar with the maintenance, operation, and calibration of specific flow measuring equipment.

Equipment and Supplies

This list may vary depending on the type of equipment used.

- Meter instruction manual
- Flow meter/calculator or headset
- Sensor cable or wiring connections
- Impeller / velocity sensor
- Spare bearings
- Oil lubricant for bearings
- Batteries
- Top-setting rod
- Tape measure
- Stopwatch
- Rating tables
- Velocity angle correction chart
- Data sheets
- Tools (e.g. pliers, 1/16" Hex wrench, large and small screwdrivers, flashlight)
- For bridge measurements add:
    a. Safety equipment (highway cones and vests; steel toe shoes)
    b. Bridge crane and sounding reel (winch)
    c. 30C and 50C sounding weights with hanger bars and pins

Calibration and Standardization

Check the instrument for damage to cable, sensor, and other components. Open the battery compartment and check for moisture or corrosion. Check that all parts and supplies are present. This list may vary slightly depending on the type of meter. Follow manufacturer's "zero velocity test" or "spin test" as appropriate for the type of meter being used.

Methods

Select a suitable section to make the measurement. The channel should have as much straight run as possible, and be relatively free of flow disturbances such as side-streams, obstructions, or submerged debris. Areas with relatively smooth bottoms and even velocities are best. Avoid turbulent areas, eddies, or dead zones. The quality of the section can sometimes be improved by removing rocks or obstructions before making any measurements. The ideal cross-section is at least five channel widths downstream from a riffle, and two channel widths upstream from a flow control such as a riffle or rock ledge.

When measuring flow from a bridge, one must decide whether to work from the upstream or downstream side. Safety factors such as traffic hazards and walkways should be the first consideration. See the "Bridge Zone Safety" JSA for more information. The upstream side of the bridge often has less turbulence and streambed scour, and one can see approaching debris. The advantage of the downstream side is that the flow may be straightened out as it passes abutments and piers.

A minimum of 20-30 velocity/depth vertical profiles (if the total stream width permits) and sample times of 40 seconds or more are required to estimate true discharge within 5%.

1. Assemble flow meter and perform appropriate quality control checks. If using a flow computer make sure all settings are correct, such as the velocity meter type (e.g. Price AA), rating curve (e.g. USGS Std 2), sample time (40 sec.).
2. String a tape measure perpendicular to the majority of the flow.
3. Record the channel width and the tape readings at the wetted edges.
4. Check the configuration of the channel cross-section and depths, and the distribution of velocities.
5. Divide the channel into segments. The object is to have a maximum of 10% of the flow pass between any two sample points. An ideal measurement would have no more than 5% of the total discharge in any one subsection. Therefore, sample points should be spaced closer together in areas with greater depth and velocity.
6. At each sample point, record the distance on the tape, the total water depth to the nearest 0.1 ft, the velocity in ft/sec., and the angle correction coefficient to correct for non-perpendicular flow.

Measuring Depth

At each sample point, total depth is measured to determine the appropriate depth at which to measure velocity.

For wading measurements, depth is measured using marks on the top-setting rod. If water piles up on the front of the wading rod, read the depth by visually extending the level water surface to the rod.

For bridge measurements, the sounding reel's depth indicator is zeroed with the AA meter's cups at the water surface (the bottom of the weight is about 0.5 ft below the surface). (Note: On bridges that are not level, the depth indicator will need to be re-zeroed frequently.) The sounding weight is lowered until it hits bottom, and slack is removed from the line. The depth is read from the indicator, then 0.5 ft is added to the depth reading if using a 30C weight, or 0.55 ft is added if using a 50C weight. (Note: choose a weight that is heavy enough to maintain a vertical position in the water column.)

Measuring Velocity

Velocity is read either directly from an electronic display, or by using a stopwatch, revolution counter, and rating table. When making a measurement, aim the velocity meter into the flow. If reverse flow is encountered (i.e. an eddy), orient the velocity meter into the flow and record the result as a negative number.

Average velocity theoretically occurs at 60% of the depth. In deeper water, averaging measurements from 20% and 80% depths may give a better estimate of the true mean. Sometimes one needs to use the 20/80 method in shallow water to account for bottom obstructions.

At sample points less than 2.5 ft deep, only one velocity measurement at 60% of the depth is needed. (Exception: for Pygmy meters, only one velocity measurement is needed at depths less than 1.5 ft.) For wading measurements, set the top-setting rod to 60% of the depth. For example, in water that is 2.0 ft deep, the velocity meter is positioned 1.2 ft below the water surface. This is done by lining up the foot-scale on the sliding rod with the tenth-scale on the

handle. For example, if the total depth is 2.0 ft, line up the 2 on the sliding rod with the 0 on the handle. During measurements, hold the wading rod at the tape and be sure to stand beside and downstream of the wading rod.

For bridge crane measurements, measure the total depth as described above, then calculate the 60% depth and crank the winch handle to raise the meter until the depth indicator points to the correct depth. For example, if the water depth is 2.0 ft, crank the winch until the depth indicator points to 1.2 ft. When using the 30C weight, a minimum depth of 1.2 feet is required to measure velocity. When using the 50C weight, a minimum depth of 1.4 feet is required to measure velocity. At depths of 2.5 feet (or deeper) using the 30C weight or 2.8 feet (or deeper) using the 50C weight, it is necessary to make two velocity measurements and average them. One measurement is made at 20% of the depth and the second is at 80% of the depth. Raise or lower the current meter until the depth indicator points to the correct depth.

There are some bridges where the main flow must be measured with a bridge crane set-up, but a significant portion of the channel is too shallow. Under these circumstances the field crew would complete the transect using a top-setting rod - refer to the previous paragraph on wading measurements.

Angle Correction

An angle correction coefficient is applied if the direction of flow is not perpendicular to the cross-section. During wading measurements, the angle may be determined by observing current lines or floating debris relative to the tape measure. For bridge measurements observe the position of the flow meter and sounding weight relative to the tape. The correction is determined using the values printed on the edge of an angle correction chart. The chart is positioned on the tape measure and rotated until the edge lines up with the angle of the current. The correction values are printed on the edge of the chart. (Note: These values are also printed on the edge of AquaCalc flow computers, and on the edge of standard USGS measurement note sheets.) When calculating discharge, the velocity measurement for a sample point is multiplied by the angle correction coefficient. (Note: When using an AquaCalc flow computer, if the angle correction coefficient is entered at the start of the measurement, the AquaCalc will display and store corrected velocities. *Be sure not to re-apply the correction if data are later entered into a spreadsheet such as Flowpro.)*

Calculations and Data Reporting

Discharge is calculated using the mid-section method in which each subsection extends halfway to the preceding and following observation points. The flow through each segment is calculated by multiplying the cross-sectional area by the average velocity, as calculated at each observation point. Total discharge is the sum of the flow through each segment. For a detailed description of the mid-section method, see either of the references listed below. These calculations can be done manually, or by using the "Flowpro" spreadsheet on the WQM shared directory, or by using the AquaCalc meter's calculation function.

References

Buchanan, T.J., and Somers W.P., 1984. Techniques of Water-Resources Investigations of the United States Geological Survey, Chapter A8, Discharge Measurements at Gaging Stations. United States Geological Survey, Department of the Interior, Washington, DC.

Nolan, M.K., and Shields, R.R., 2000. Water Resources Investigations Report 00-4036, (CD-ROM version 1.1), Measurement of Stream Discharge by Wading. United States Geological Survey, Department of the Interior, Washington, DC.

OXIDATION –REDUCTION POTENTIAL

Background

Oxidation-reduction is a chemical reaction in which an atom or molecule gains or loses an electron. Oxidation-reduction potential (Eh, Redox or ORP) is the measurement of electron activity with an inert indicator electrode and a suitable reference electrode. ORP is measured in millivolts.

ORP measurements in surface water and groundwater samples are not specific for a particular ion or species, and therefore must be interpreted carefully to obtain meaningful results. Since ORP represents the potentiometric measurement of the equilibrium present between all of the oxidized and reduced species in solution, it is useful only as a qualitative measurement in natural water samples. The ORP of relatively clean surface waters is particularly difficult to determine, due to the low concentrations of ionic species. The Water Monitoring and Assessment Sections measure ORP only in groundwater samples. Typically, the ORP of groundwater samples will range from –200 to +400 millivolts, using a silver/silver chloride (Ag/AgCl) reference electrode and platinum sensor.

ORP measurements can be useful in characterizing groundwater to determine if it has reducing or oxidizing capabilities. Because it is difficult to measure and interpret, ORP is used as a qualitative tool for groundwater assessments. In general, values that are more negative represent a reducing tendency of the system, while values that are more positive represent an oxidizing tendency. ORP measurements are generally used for intra-well comparisons over time, or inter-well comparisons at a given site with multiple wells.

Method Summary

Oxidation-reduction potential is measured with a noble metal (platinum) sensor, and an Ag/AgCl reference electrode system, using a pH meter that can read in millivolts. The lab has a single meter and probe dedicated for ORP measurements. However, any of our pH meters with a millivolt setting and the proper electrode will work. A standard solution of known ORP is used to check the accuracy of the meter and electrode. The Water Monitoring and Assessment (WMA) Sections use Light's solution, as a standard. There are other standard solutions available (APHA, et al., 1998).

The ORP probe reading is dependent on the inert metal (usually platinum or gold) used in the indicator electrode, and on the reference electrode filling solution. To compare ORP readings from different sources, the readings are normalized to the Hydrogen electrode. The WMA Sections report ORP as read from the meter (Ag/AgCl reference and platinum sensor electrode), not as normalized to the Hydrogen electrode.

Equipment and Supplies

ORP meter: Beckman Model 11, or equivalent. Any meter capable of measuring absolute millivolts is acceptable. ORP should be measured in absolute millivolts, not relative millivolts.

ORP electrode: Corning 476516. This electrode consists of a reference electrode (silver: silver chloride with saturated KCL filling solution), and a platinum sensor electrode combined into a single probe.

ORP measurement container: A special container should be used when taking ORP measurements. The container is important because it helps to minimize disturbance to the sample

while the reading is being made, and reduce the sample's exposure to atmospheric oxygen. The ORP container consists of a small plastic jar to hold the water sample, with a screw-on lid that has 2 holes in it to insert the ORP electrode and the temperature probe. A flow-through cell may also be used for ORP measurements. If the ORP container is unavailable, the ORP can be measured from a sample in a beaker. Exposure of the sample to atmospheric oxygen may affect the accuracy of the ORP measurement.

Light's Solution: A solution of known electrical potential is necessary to check if the meter and electrode are functioning properly. Light's solution has an electrical potential (ORP) of +476 at 25° C, when measured with an Ag/AgCl reference electrode and a platinum sensor. The standard solution measurement, made at a stable temperature of 25° C, with a properly functioning electrode system, should be accurate to within plus or minus 10 millivolts. The DEQ Laboratory Inorganic Section prepares the Light's solution. See Reference 1 for the formula for preparation of the Light's solution.

The Light's solution should be stable for six months following its preparation. Always use Light's solution from the 1-liter volumetric flask standard solution for the laboratory meter check. A plastic screw-top container should be filled with Light's solution before each sampling event for a meter field check.

Methods

Meter check (laboratory)

1. Fill a beaker with Light's solution from the volumetric flask. Equilibrate the Light's solution to 25 (±1) °C. Use the constant temperature (25° C) water bath in the meter calibration room.
2. Use a shorting lead (shunt) to verify the zero point on the meter millivolt scale. Follow the meter manufacturer's recommendations for shorting the meter.
3. Immerse the probe in the Light's solution.
4. Assure that the meter is reading in absolute millivolts.
5. Allow several minutes for the electrode to equilibrate, and record the reading to the nearest millivolt.
6. If the meter reads greater than ±10 millivolts from the standard, follow the troubleshooting guidelines.

Troubleshooting Guidelines

Assure that the Light's solution was made within the last six months. If not, ask the Inorganic Section chemist responsible for preparing it to make up fresh solution. Recheck the meter with fresh Light's solution.

If the meter reading on the standard solution is greater than ± 10 millivolts from the theoretical value, follow the manufacturer's guidelines for probe maintenance. These may include:

1. Replace the electrode filling solution (saturated KCL).
2. Polish the sensor end of the platinum electrode, following the manufacturer's recommendations. Crocus cloth, extra fine sandpaper, steel wool, or a hard pencil eraser may be used for polishing the surface. Rinse the electrode and try again.
3. The electrode may be cleaned by immersion in a strong acid. Follow the manufacturer's recommendations.

4. Replace the old electrode with a new electrode.

Sample Analysis

1. Assure that the meter is reading in absolute millivolts.
2. Check the meter on Light's solution daily, prior to sampling. Rinse the probes with distilled water, and immerse in the Light's solution. Record the millivolt reading and the temperature. It is not practical to maintain the Light's solution at 25°C in the field, so the value may not be within 10 millivolts of 476 millivolts. Rinse the probes in distilled water.
3. Collect the water sample, preferably in the ORP container. Minimize turbulence and aeration while collecting the sample. Take the reading as soon as possible after collecting the sample to assure a representative measurement. (If a flow-through cell is used, place the meter probes in the cell).
4. Rinse the electrodes thoroughly with sample water, and immerse them in sample in the ORP container (or a small beaker).
5. Allow a few minutes for equilibration, and record the reading to the nearest millivolt. Record the temperature of the sample to the nearest tenth of a degree centigrade. (For a flow-through cell, maintain a steady, laminar flow, and record the reading. Turbulent flow or aeration of the sample may prevent a stable reading from being obtained.)
6. Store the probes in a beaker of sample water or distilled water between samples.
7. Always report both the ORP reading and the temperature of the sample at the time of the reading.

Interpretation of Results

The WMA Sections use ORP measurements in groundwater as an indicator of a reducing or oxidizing environment. Changes in the ORP at a specific sample point over time may indicate changes in groundwater quality. Differences in ORP readings between wells at a specific site may help to determine impacts to groundwater quality from contaminant plumes. Because of the multiple oxidation-reduction reactions that can occur in most groundwater samples, ORP measurements are used for qualitative purposes only.

The WMA Sections report ORP, as measured with an Ag/AgCl reference electrode, and platinum sensor electrode. Any comparisons with other ORP measurements, that were made using a different electrode system, need to recognize the differences that will occur based on the electrodes used. Normalization of the readings to the Hydrogen reference electrode may be possible (see references below) for comparison purposes.

References

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HABITAT

Overview

Habitat is the sum of the physical features of a water body. It includes stream channel, riparian and greater watershed attributes. Stream habitat assessments conducted by the DEQ Water Monitoring and Assessment (WMA) sections typically deal with stream channel and riparian area reach length attributes. This section will briefly examine why habitat is important, what sorts of habitat attributes are measured, spatial and temporal scale consideration in habitat assessments, and references for habitat protocols typically used by the WMA Sections of DEQ. Unlike other sections of this manual, this section does not prescribe specific protocols but discusses general considerations in habitat monitoring and gives references to protocols for those wanting more information on specific methods.

Why habitat is important

The habitat quality of a stream or river, along with the chemical water quality, is critical in determining the ecological or biological integrity of a water body. A water body is in good condition if the habitat and chemical water quality are both of sufficient quality to support the natural species assemblage and abundance that would be expected in the absence of human alteration to the system. Habitat degradation can have significant effect on the stream biota even if the chemical water quality is unimpaired. An example of this in Oregon is the federal listing of several species of wild salmon under the Endangered Species Act (ESA) in watersheds with excellent chemical water quality but seriously degraded spawning and rearing habitat due to a history of logging and road building in the watersheds. Human activities can have a negative effect on habitat condition if they involve draining or filling wetlands, removal or alteration of riparian vegetation, or simplification of the natural complexity of a stream channel.

Types of habitat attributes

The following is a list of habitat attributes typically included in DEQ WA Habitat Assessments.

- Channel dimensions
- Channel gradient
- Channel complexity
- Fish cover
- Riparian vegetation cover, structure, and composition
- Human activities and alteration
- Channel-riparian interactions
- Substrate characteristics

Spatial and temporal scale

Spatial and temporal scales involved in stream habitat surveys can vary widely depending on the purpose of the monitoring program. For example, the spatial scales for collecting channel characteristics and riparian shade data for basin-wide stream temperature Total Maximum Daily

Load (TMDL) assessments will be very different from one used in a reach scale restoration effectiveness assessment even though both assessments are measuring the same habitat attributes. Different temporal scales for measuring habitat parameters are also an important consideration. For example, in some assessments it may be necessary to evaluate channel complexity and riparian processes under different seasonal flow conditions, or in a single season over a span of several years to track changes after restoration. These factors should be addressed in the monitoring study plan. The specific habitat monitoring approach used will depend on the questions being asked and purpose of the study.

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CHAPTER 5 – CONTINUOUS MONITORING METHODS

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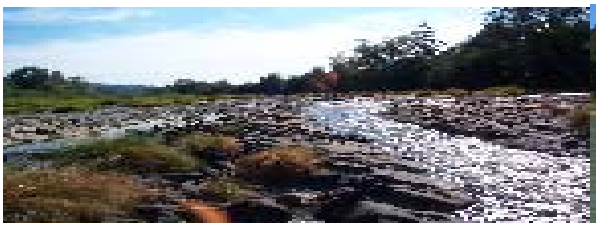
GENERAL CONSIDERATIONS



Background

This section is an introduction to the continuous monitoring chapter of MOMs. Specific questions regarding continuous monitoring equipment should be referred to the appropriate equipment-related section.

DEQ uses a variety of continuous monitoring equipment, the selection of which is dependent on the specific data requirements. To measure or characterize both spatial and temporal variability, continuous monitoring devices use a series of observations, measurements, or samples collected over time and can be placed in various locations within a study area. Although the physical location of the monitoring station may dictate the type of equipment to be used, the following items should be considered in the selection of continuous monitoring equipment type and locations:

What parameters does the QAPP require to be continuously monitored and for what duration?
Define study objectives

What are the primary beneficial uses, ownerships of the water in the study area?
Agricultural, Recreational, Public/Private Lands, Fish?

What are the locations and the effects of point source discharges; how do these sources contribute to the system?
Bracket point sources such as treatment plants, outfalls, drainage, etc

What are the locations and the effects of non- point source discharges; how do these sources contribute to the system?
Bracket non-point source areas/catchments

Is there a need to bracket the tributary with monitoring equipment?
Define and monitor tributary locations; tributary may be able to be studied without the use of continuous monitoring equipment (i.e. grab samples).

What are the spatial characteristics of the water body to be studied?
Define areas of run, riffle, pool, flat, etc. Define habitat, type of stream bed, depth of stream, channel geometry, etc.

What seasonal effects/characteristics are prevalent in the study area?
Changes in characteristics: seasonal, depth, turbulence

Are there structures (weirs, dams, reservoirs etc.) that will affect the type of monitoring data collected for the study area?

Primary/secondary device (weir/flume, automated flow meter) may impede effective sampling. Consult user manual or site operator to determine where most representative sample may be collected

What are the accessibility/security options?
Are there tidal effects? (Estuarine conditions)?

If the study objective is to investigate a specific water use, such as a source of water supply, recreation, or other discrete use, then considerations such as accessibility, flow, velocity, physical characteristics, etc., may not be critical from a water quality investigation standpoint. If the objective of a water quality study is to determine patterns of pollution, or provide data for mathematical modeling purposes (i.e. TMDL), where more than a small area or short stream reach is to be investigated, then several of the factors listed above become interrelated and need to be considered in selection of a representative sampling location.

Site Reconnaissance

Before any sampling is conducted, an initial reconnaissance should be made to locate suitable continuous monitoring locations. Bridges and piers are normally good choices as monitoring sites, since they provide ready access for water sampling at any point across the width of the water body. However, these structures may alter the nature of water flow and are prone to vandalism. Additionally, bridges and piers are not always located in desirable locations with reference to waste sources, tributaries, etc. Wading for water samples in lakes, ponds, and slow-moving rivers and streams must be done with caution, since bottom deposits are easily disturbed, thereby resulting in increased sediments in the overlying water column.

On the other hand, wade-able areas may be the best choice for sediment sampling. In slow-moving or deep water, a boat may be required for sampling. Sampling station locations can be chosen without regard to other means of access if the stream is navigable by boat, especially in estuarine systems where boats frequently provide the only access to critical sampling locations. Landowners should always be contacted prior to establishing a sample station on a waterbody on or adjacent to their property.

Fresh water environments are commonly separated into two types:

1. Flowing water, including rivers, creeks, and small to intermittent streams; and
2. Water that is contained, with restricted flow including lakes, ponds, and manmade impoundments (i.e. reservoirs)

Since these waterways differ considerably in general characteristics, site selection must be adapted to each type. Estuarine environments are a special case and are discussed separately.

Rivers, Streams, and Creeks

In the selection of a surface water sampling site in a river, stream, or creek, an area that exhibits the greatest degree of cross-sectional homogeneity should be located. Where available, previously collected data (i.e. LASAR, STORET, NWIS, etc) may indicate if potential sampling locations are well mixed, or

vertically or horizontally stratified. Since turbulence and water velocity govern mixing, the selection of a site immediately downstream of a riffle area will insure good vertical mixing. These locations are also likely areas for deposition of sediments since the greatest deposition occurs where stream velocities decrease, provided that the distance is far enough downstream from the riffle area for the water to become quiescent (calm). Horizontal (cross-channel) mixing occurs in constrictions in the channel, but because of velocity increases, the stream bottom may be scoured, and therefore, a constriction is a poor location to collect data.

Typical sediment depositional areas are located:

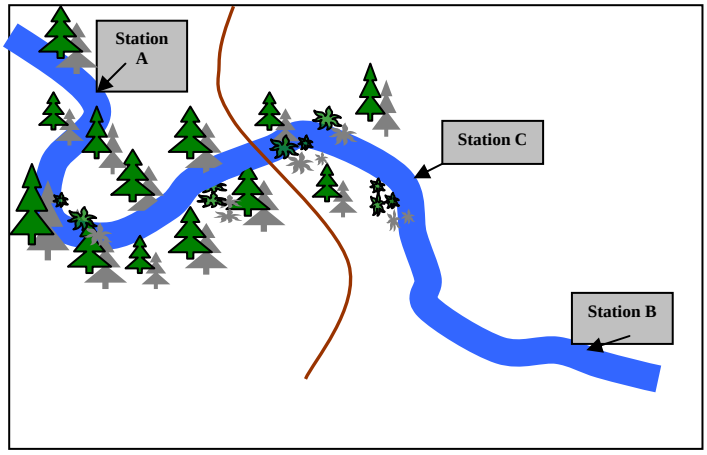
- Inside of river bends;
- Downstream of islands;
- Downstream of obstructions; and
- Areas of flow reversals.

Sites that are located immediately upstream or downstream from the confluence of two streams or rivers should generally be avoided since flows from two tributaries may not immediately mix. Back-flow from the tributary stream may change the depositional flow patterns of the main-stem stream.

When several locations along a stream reach are to be sampled, they should be strategically located:

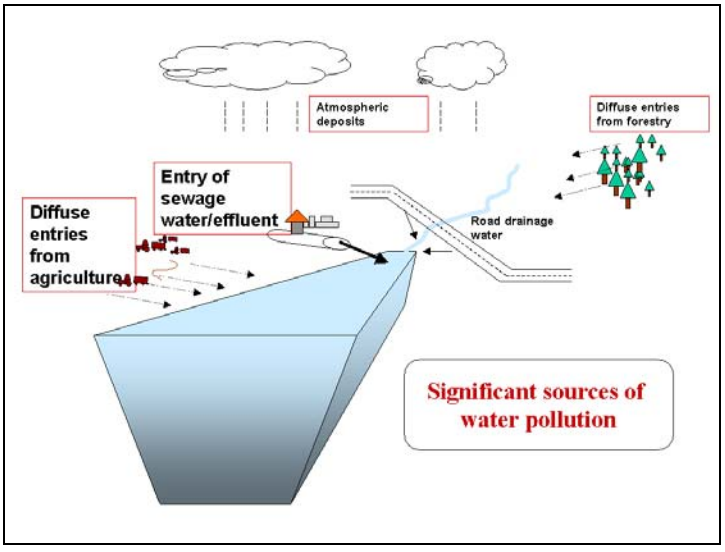
- At intervals based on time-of-water-travel, not distance, sampling stations may be located about one-half day time-of-water-travel for the first three days downstream of a waste source (the first six stations) and then approximately one day through the remaining distance. Time of travel may be an important consideration for specific studies (dilution of pollutants, gas diffusion rate, and nutrient up-take rate); however, the interval (half day/three day) would vary depending on the study needs. Time of travel may be determined by a number of methods, including Discharge = Velocity * cross-sectional Area (Q=VxA), Dye Study, and historical discharges.
- At the same locations, if possible, when the data collected are to be compared to data from a previous study (use existing LASAR, STORET, USGS stations where applicable).
- Whenever a marked physical change occurs in the stream channel. Example: A stream reach between two adjacent stations should not include both a long rapids section of swift shallow water with a rocky bottom, and a long section of deep, slow-moving water with a muddy bottom. Stations at each end of the combined reach (stations A &B, **Figure 1**) would yield data on certain rates of change, such as re-aeration, that would be an unrealistic average of two widely different rates. The actual natural characteristics of the stream would be better defined by inserting a third sampling station (Station C, **Figure 1**) within the reach, between the rapids and the quiet water sections.

Figure 1 Example Stream Reach



- When major changes in a stream reach occur, an upstream station, a downstream station, and an intermediate station should be selected (**Figure 2**). Major changes may consist of:
    - A wastewater discharge;
    - A tributary inflow;
    - Non-point source discharge (farms or industrial sites); and
    - A significant difference in channel characteristics.

Figure 2 Example Changes in a Stream Reach



- To isolate major in-stream structures, as well as major tributaries. Dams and weirs can cause changes in the physical characteristics of a stream. They usually create quiet, deep pools in river

reaches that previously were swift and shallow. Such impoundments should be bracketed with sampling stations. When time-of-water-travel through the pools is long, stations should be established within the impoundments. Some structures, such as dams, permit overflow and cause swirls in streams that accomplish significant re-aeration of oxygen-deficient water. In such cases, stations should be located short distances upstream and downstream from the structures to measure the rapid, artificial increase in dissolved oxygen, which is not representative of natural re-aeration.

- Consideration should also be given to the accessibility and practicality of monitoring stations.

Unless a stream is extremely turbulent, it may be difficult to measure the effect of a waste discharge or tributary immediately downstream from the source. The inflow frequently "hugs" the stream bank due to differences in density, temperature, and specific gravity, and consequently lateral (cross-channel) mixing does not occur for some distance. Tributaries should be sampled as near the mouth as feasible. On large rivers, the mouths of tributaries are accessible by boat. Care should be exercised to avoid collecting water samples from stratified locations, which are due to differences in density resulting from temperature, dissolved solids, or turbidity.

Lakes and Reservoirs

If the water body of interest is a lake (**Figure 3**) or reservoir (**Figure 4** and **Figure 5**), organizers should identify how data collected will be used and who will use it. Data can be used to establish baseline conditions, determine trends in water quality, or identify current and emerging problems. Initially, the project coordinators must make several important decisions in the development of a monitoring program. Project coordinators must decide:

- What the major goal of the study program will be;
- What existing or potential lake/reservoir condition will be the focus of monitoring;
- Are vertical profiles needed? (Procedures for vertical profiling in Multi-Parameter Logger section of MOMs)
- What sampling locations will best characterize the water body (deepest point in lake/reservoir, near inlets/outlets, near anthropogenic sources?);
- What sampling parameters should be used to characterize the selected lake condition (nutrients, dissolved oxygen, temperature, etc);
- What procedures should be used to sample each parameter (for example, are there low level nutrients that may dictate estimating concentrations below the Minimum Detection Level (MDL)?);
- How employees/volunteers will be trained; and
- How the results of monitoring will be presented.

Once the monitoring program is established, the monitoring personnel and project managers should meet periodically to evaluate it, update objectives, and fine-tune activities. This review should ensure that the monitoring efforts continue to provide useful information to those who need lake/reservoir data.

Figure 3 Lake

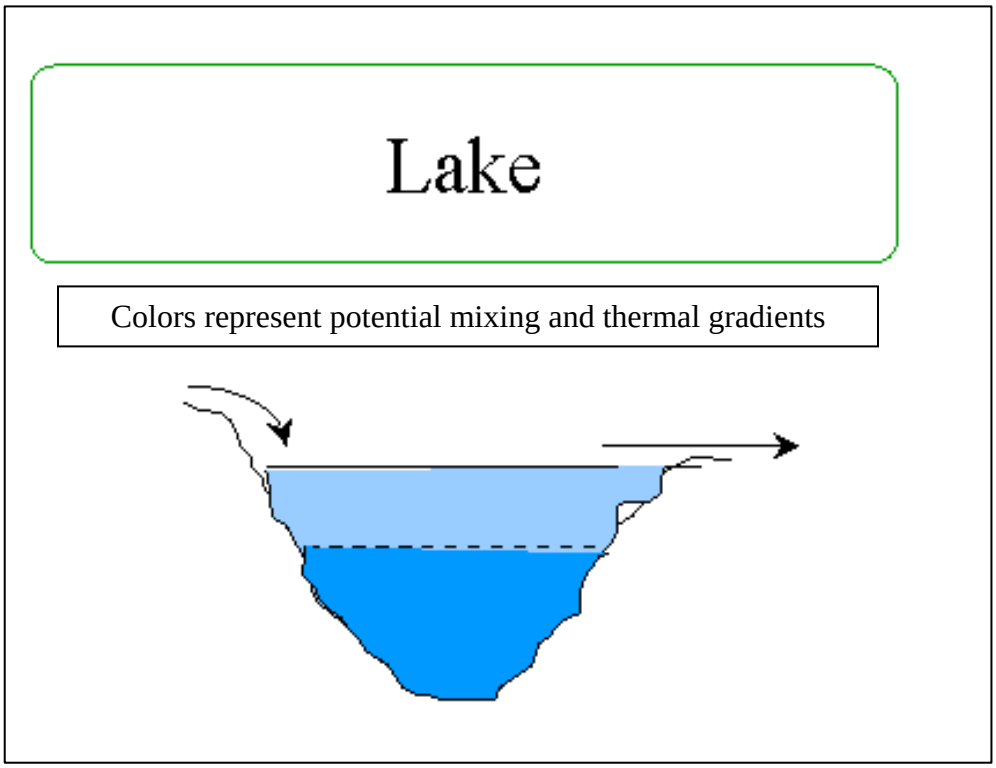


Figure 4 Reservoir

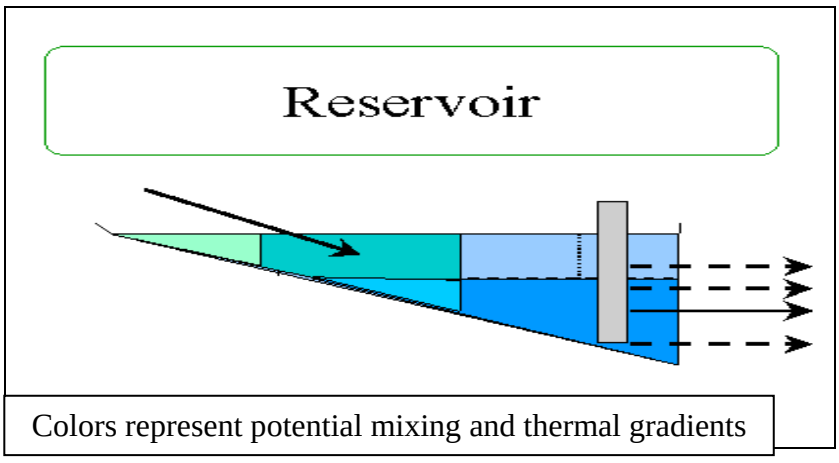
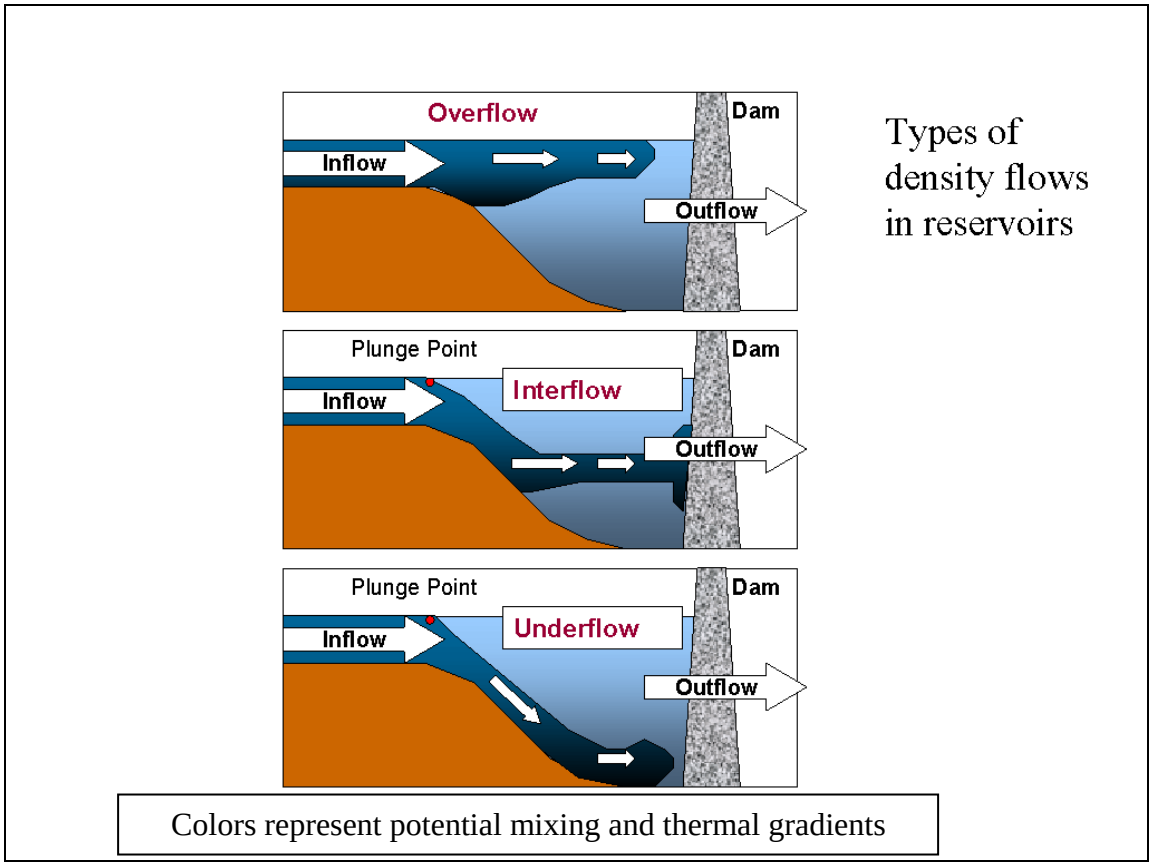


Figure 5 Density Flows in Reservoirs



Estuaries

Estuarine areas are zones where inland freshwaters (both surface and ground) mix with oceanic saline waters. Estuaries are generally categorized into three types, dependent upon freshwater inflow and mixing properties:

- Mixed estuary -- Characterized by an absence of vertical halocline (gradual or no marked increase in salinity in the water column) and a gradual increase in salinity seaward. Typically, this type of estuary is found in major freshwater sheet-flow areas, featuring shallow depths.
- Salt wedge estuary -- Characterized by a sharp vertical increase in salinity and channeled freshwater inflow into a deep estuary. In these estuaries, the vertical mixing forces cannot override the density differential between fresh and saline waters. In effect, a salt wedge tapering inland moves horizontally, back and forth, with the tidal phase.

- Oceanic estuary -- Characterized by salinities approaching full-strength oceanic waters. Seasonally, freshwater inflow is small with the preponderance of the fresh and saline water mixing occurring near, or at, the shoreline.

A reconnaissance investigation should be conducted for each estuarine study, unless prior knowledge of the estuarine type is available. The reconnaissance should focus on the freshwater and oceanic water dynamics with respect to the study objective. National Oceanic Atmospheric Administration (NOAA) tide tables and United States Geological Survey (USGS) freshwater surface water flow records provide valuable insights into the estuary hydrodynamics.

The basic in-situ measurement tools for reconnaissance are:

- Boat;
- Recording fathometer;
- Salinometer;
- Dissolved oxygen meter; and
- Global Positioning System (GPS) equipment and charts.

These instruments, coupled with the study objective or pollution source location, (whether it is a point or non-point source problem), provide the focus for selecting sampling locations. More often than not, preplanned sampling locations in estuarine areas are changed during the actual study period. Because of the dynamics of estuaries, the initial sampling results often reveal that the study objective could be better served by relocating, adding, or deleting sampling locations. Water sampling in estuarine areas is normally based upon the tidal phases, with samples collected on successive slack tides. All estuarine sampling should include vertical salinity measurements at one to five-foot increments coupled with vertical dissolved oxygen and temperature profiles. A variety of water sampling devices is used, but in general, the Van Dorn (or similar type) horizontal sampler or peristaltic pump are suitable.

Samples are normally collected at mid-depth in areas where the depths are less than 10 feet, unless the salinity profile indicates the presence of a halocline (salinity stratification). In that case, samples are collected from each stratum. Depending upon the study objective, when depths are greater than 10 feet, water samples may be collected at the one-foot depth from the surface, mid-depth, and one-foot from the bottom. Generally, estuarine investigations are two-phased, with study investigations conducted during wet and dry periods. Depending upon the freshwater inflow sources, estuarine water quality dynamics cannot normally be determined by a single season study.

Methods and equipment used for continuous monitoring of surface water bodies, as well as site selection, will be determined by QAPP plans and data objectives/needs.

Technical Considerations

Testing for Realistic Performance Data

Often, in the absence of experience or referral, the only information available to buyers of water quality instrumentation comes from the manufacturer's specification sheet, which lists among other things, features, options, physical characteristics, and instrument accuracies. These accuracy figures are often the

key to a decision to purchase. On the other hand, DEQ experience shows that it is unwise to rely solely on manufacturer data.

There is really just one way to determine whether field readings are good enough for a specific application. The operator must periodically check their instrument with a full range of controlled tests (i.e., audits) that duplicate field situations. For instance, if a conductivity stem is calibrated in the lab with a 1413 micro µmhos/cm KCl solution at 25°C after an equilibration time of 10 minutes, does the operator know what really happened under field conditions of 4°C temperature, 5 atmospheres pressure, a sample flow of 3 feet per second, a station time of 45 seconds, with a sample whose 24 µmhos/cm conductivity is due not to KCl but to sulfuric acid? The manufacturer's specifications and the calibration procedure simply don't give enough information to correctly extrapolate laboratory accuracies to exacting field work.

Accuracy, Uncertainty, and Error

Accuracy is a misleading, catch-all term used to simplify specification sheets of equipment ("uncertainty" and "error' are often used synonymously). Accuracy is the difference between the system reading and the "true" value. It can be specified as a percentage of the reading, a percent of the full-scale reading, or as plus-or-minus fraction. Accuracy is strongly influenced by several operator-controlled variables, such as the quality of calibration standards, station residence time, sensor maintenance, and calibration technique and frequency. Since a manufacturer cannot anticipate these conditions, stated accuracies assume ideal measurement conditions. It becomes the burden of the operator to make his instrument perform to the manufacturer specifications.

There is no single, easy way to determine accuracy. Instead, the components of accuracy, whether they are controlled by instrument design or operator procedure, must be tested individually. The COMPONENTS of ACCURACY section below describes the tests required to quantify each component or influence important in field water-quality measurements. These include linearity, response time, sensitivity to pressure, temperature, flow, and drift.

COMPONENTS of ACCURACY

Linearity and Tracking

Linearity is the relationship between the instrument's reading and a parameter's true value. A parameter displaying small, non-constant deviations from a slowly changing true value implies non-linearity. As an example, if errors detected in the testing of a temperature system varied randomly from -0.2 to +0.4°C the system might be, depending on the operating requirements, considered nonlinear. Constant, predictable deviations from true value more likely represents linearity, a situation that the operator can correct or adjust for. To continue the previous example, if the errors increased slowly and consistently from -0.2 to +0.4°C the error could be corrected by adjusting slope and zero, so this would be more a problem of miscalibration than of non-linearity. Further, if the errors ranged from -0.006 to +0.005°C the system might be considered linear because the deviations are small.

The test for linearity involves methodically changing only the true parameter value and plotting the true value against the system's reading. The true value is defined by independent measurement instruments calibrated and maintained according to MOMs. Principles of linearity testing are:

a) Deciding the pertinent range of values to be tested, and the maximum acceptable deviation, due to non-linearity from the true value;
b) Performing scrupulous maintenance and calibration of the entire measurement system according to the manufacturer's recommendations;
c) Preparing test solutions that provide at least three measurement points (five are better) over the range, including the endpoints, to limit as much as possible the variability to only the parameter being tested;
d) Allowing sufficient time for sensor equilibration at each test point; and
e) Recording the true values and the system's readings at each point, analyzing for acceptable non-linearity, and saving the information for future reference.

Response Time

Response time is the time required for a system to react, by a prescribed amount, to a step change in some variable. The extent of the response must be stated, as in "a 90% of total change" or "to within 0.1 mg/L of the final reading" (for the case of dissolved oxygen). Ideally, the requirements should be defined by the operator to suit their particular need so that a response test can be designed accordingly.

An appropriate lab test for response time is to switch the sensor from a controlled environment (for instance, a water bath) with one value of the parameter being examined to another environment with a different value, and to note the system's reading as it changes with time. Principles of response testing are:

a) deciding the pertinent test endpoints (extremes in true value), and the required sensor response, in a given time, to be acceptable;
b) performing scrupulous maintenance and calibration of the entire measurement system according to the manufacturer's recommendations;
c) preparing solutions of the correct endpoint values, with the variability limited as much as possible to the test parameter and time.
d) recording the real-time readings versus response time readings, analyzing the data for unacceptable temporal sensitivity, and saving the results for future reference.

Pressure-sensitivity testing in a pH system

If a water column (such as a lake) is being used to produce the required pressure, care should be taken to note large changes in temperature and pressure as the sensor descends, since changes in a reading due to changes in temperature of the standard or sensor might be indistinguishable from those changes caused by changing pressure. There are many sources of error with continuous monitoring equipment; being able to notice what is a true change in pH versus what pH values may be falsely influenced by temperature or pressure variances is a good QC practice.

Flow Sensitivity

Sensitivity to flow is a measure of a sensor's tendency to produce a different final reading when the flow rate of sample changes. This problem is known to affect dissolved oxygen readings (including, to one extent or another those made with special "no-flow" dissolved oxygen sensors) and sometimes pH readings made in low ionic-strength solutions.

Flow sensitivity can be checked by a step-wise change in the flow characteristics of the solution being tested. The principles of flow sensitivity testing are:

a) deciding the pertinent range of flow rates that must be examined, and the acceptable deviation, due to flow sensitivity, from the true value;
b) performing scrupulous maintenance and calibration of the entire measurement system according to the manufacturers specifications;
c) facilitating the change of flow rate in the sample to provide at least three test points over the range, with the variability limited as much as possible to flow rate;
d) allowing for sensor equilibration at each test level; and
e) Recording the system reading versus flow rate, analyzing the data for unacceptable sensitivity, and saving the results for future reference.

Drift

Drift is the long term lack of repeatability caused by influences such as fouling of the sensor, shifts in the calibration of the system, or slowly failing sensors. There are many ways to quantify drift, so testing should be done not necessarily to verify a manufacturer's specifications, but to provide useful data to a field operator for his specific field situation. Because testing for drift is based on the often difficult-to-duplicate in-situ field conditions, there are no set rules for drift quantification; post-calibration is perhaps the best indicator of drift under field conditions.

For example, the air-calibration reading of a dissolved-oxygen sensor might change as the membrane deteriorates and becomes fouled, from 8.4 mg/l to 7.6 mg/l over a week of continuous field duty. Under similar conditions, the operator might take this information into consideration and reduce the field deployment time to four days so that the total drift will be reduced. Alternatively, a table built on post-calibration data is a possible remedial correction for drift.

The operator must also recognize causes of short-term conflict. For instance, dissolved oxygen readings may not stabilize for a few hours after a new membrane is installed; calibration should be postponed until the readings stabilize.

Hysteresis

Hysteresis error is a difference in parameter readings that occurs because the time under which the sensor approached the readings varied. For instance, a pressure (depth) transducer might read 5.1 meters when lowered from the surface to the five-meter level. However, if the transducer was lowered to 100 meters before returning to the five-meter level, the reading might be 5.5 meters. The difference between the 5.1 and 5.5 meter readings is a hysteresis error.

Notice that hysteresis error must be isolated from subtle influences by other effects. Any electronic pressure transducers, for example, are sensitive to temperature; different readings under the same pressure input can be caused by lack of thermal equilibrium between the sensor and the sample. Long response times to changes in parameter values can also produce readings that only seem to be hysteretic.

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TEMPERATURE LOGGERS

Scope and Application

The WA section measures temperature in grab samples and conducts long-term studies in which temperature is measured continuously with data loggers. Techniques for measuring temperature in grab samples collected as part of standard field parameter measurements and for auditing continuous temperature monitoring devices are covered in Chapter 4.

The field methods describe here are for obtaining representative long-term, continuous stream temperatures from perennial streams for regional monitoring. Continuous temperature monitoring sensors are also applicable for other types of temperature study, such as mixing zone studies and point source monitoring. The field methods are specifically applicable for the deployment of continuous monitoring temperature sensors (e.g., Vemcos, **Figure 6**). Possible interferences in the accurate and precise measurement of stream temperature include:

- exposure of the sensor to ambient air,
- improper calibration procedures, including date and time settings,
- improper placement of the sensor in the stream, or water body
- low battery,
- inherent malfunctions in the sensor or data logger, and
- vandalism

Figure 6: Vemco Loggers and Interface

All continuous stream temperature monitoring sensors should be calibrated against a National Institute of Standards and Technology (NIST) traceable thermometer. Sensors not meeting precision and accuracy data quality objectives should not be used. Sensors should be placed in a well-mixed zone, e.g., at the end of a riffle or cascade. Monitoring location should represent average conditions — not pockets of cold water or isolated hot spots. Location of sampling points should either avoid or account for confounding factors that influence stream temperatures such as:

- confluence of tributaries
- groundwater inflows
- channel morphology (particularly conditions that create isolated pools or segments)
- springs, wetlands, water withdrawals, effluent discharges, and other hydrologic factors
- beaver ponds and other impoundments

The sensor should be placed toward the thread or thalweg of the channel. Keep in mind that flow will decrease throughout the summer and this may result in an exposed sensor. The thermistor portion of the device should not be in contact with the bottom substrate or other substrate that may serve as a heat sink (e.g., bridge abutment or boulder). Secure the sensor unit to the bottom of the channel with aircraft cable,

Temperature Logger

surgical tubing, re-bar, or diver's weights. The sensor should be set to record temperatures **at sampling intervals that should not exceed 1.0 hour (60 minutes**).

Equipment and Supplies

The following are typical sampling frequencies and storage capacities of a Vemco® Temperature Data Logger used for stream temperature monitoring:

Memory Type: Non-volatile EEPROM

Data Retention: 20 years

Standard Memory Capacity: 10,836 temperature readings

Power Supply: Single Lithium Cell, 1/2 AA size.

Battery Life: 5 years or 1200 full deployments.

Logging Interval: 1 second to 6 hours.

Logging Duration: 3 hours to more than 5 years.

Temperature Range: Factory preset to one of the following:

-5 to 40^{o}C	0.015 ^{o}C resolution / ± 0.1 ^{o}C accuracy
-40 to 50^{o}C	0.05 ^{o}C resolution / ± 0.2 ^{o}C accuracy

Thermal Time Constant (Response Time): Typically 45 seconds in stirred liquid.

Case:

TX - Thin walled epoxy cylinder, 16 mm diameter x 71 mm length. Minimum diameter case can be fastened with nylon cable tie loop in non-sensor end.

TR - PVC cylinder, 22 mm diameter x 95 mm length. Can be fastened through a 0.25-inch hole in non-sensor end.

Weight: **TX** - 23 g in air, 10 g in water

TR - 41 g in air, 12 g in water.

Maximum Depth: **TX** - 340 m

TR - 1000 m (TR)

Full Memory Download Standard 16 k - 6 minutes

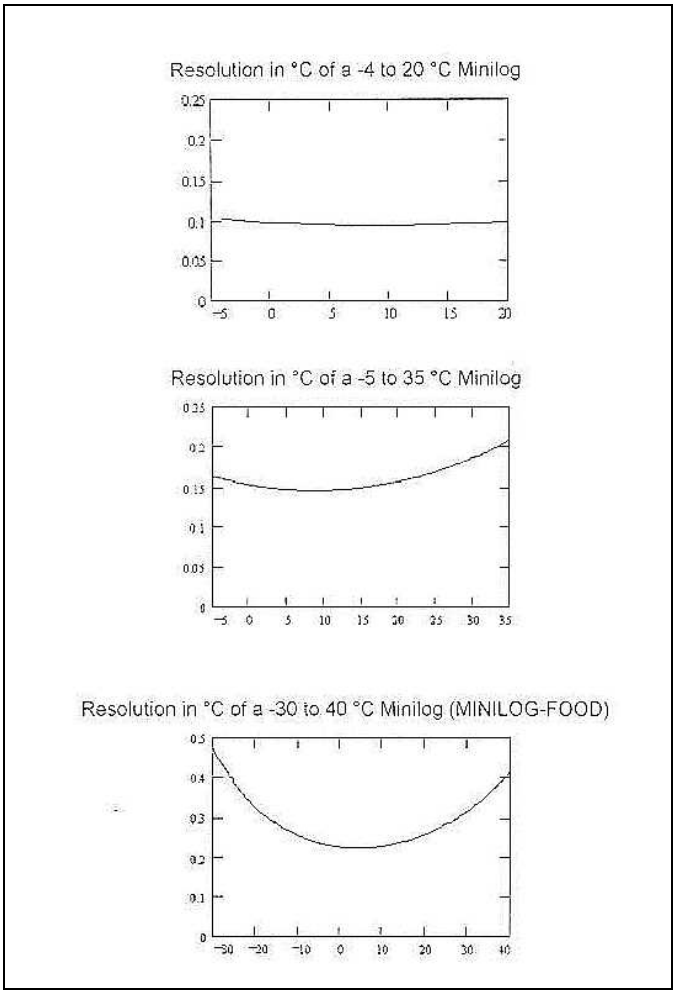
Temperature Range and Resolution: The temperature resolution depends on the range of temperature the Minilog12 can record. The following graphs (**Figure 7**) show the resolution for the standard ranges, -5 to 40^{o}C and -40 to 50^{o}C.

Minilog-PC Interface Specifications:

The Minilog-PC Interface connects the Minilog12 to a PC via the computer's RS-232 port. This allows setup information and data to be transferred between the Minilog12 and the PC. The Minilog-PC system

includes an interface unit, 1 m of cable terminated with a 9-pin "D" connector and Windows or DOS based Minilog12 software on 3.5" diskette. A user replaceable 9V battery (included) powers the Minilog-PC interface. For first time purchasers of Minilog12s, at least one Minilog-PC interface is required.

Figure 7 Minilog Temperature Resolution



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Calibration Equipment

Prior to deployment of sensors, calibration of each sensor must be performed. The following is a list of equipment and supplies for calibration:

- NIST traceable thermometer - resolution of 0.2°C or better, an accuracy of ±0.2°C or better.
- controlled-temperature water bath, or water-filled thermos or ice chest laboratory notebook
- ice

Installation Equipment

There are several useful materials and pieces of equipment that should be taken to the field to install or service temperature sensors. These include:

- securing material such as zip ties, bailing wire, aircraft cable, surgical rubber tubing, locks, re-bar, cinder blocks, large rocks with drilled holes, diver's weights
- surveyors marking tape or flagging
- sledge hammer (e.g., two-pound)
- wire cutters and/or pocket knife
- portable computer or interface for data downloading and launching
- backup batteries (for NIST thermometer) and additional thermistors
- timepiece/watch
- Rite in the Rain field book
- NIST-traceable auditing thermometer
- Waders
- camera and film
- brush removal equipment (e.g., safety axe)
- maps and aerial photos
- metal stakes or spikes, re-bar

Calibration and Standardization

Pre- and Post-Deployment Calibration and Standardization

1. A NIST-traceable thermometer must be used to test the accuracy and precision of the temperature sensors. The NIST-traceable thermometer should be calibrated annually, with at least two calibration points between 5°C (41°F) and 25°C (77°F). Calibrations should be performed using a thermally

stable mass of water, such as a controlled-temperature water bath, or water-filled thermos or ice chest. The stable temperature of the insulated water mass allows direct comparison of the unit's readout with that of the NIST-traceable thermometer. Accuracy of the NIST-traceable thermometer must be within ±0.2°C.

2. Prior to use, all continuous monitoring devices should be calibrated at room temperature (~25°C, 77°F) and in an ice water bath to insure that they are operating within the accuracy over the manufacture's specified temperature range. Calibrate all continuous monitoring devices with a NIST-traceable laboratory thermometer at two temperatures, room temperature (i.e., ~25°C, 77°F) and near the freezing point of water as follows:
   a. When calibrating and prior to deployment, set all units to the same current date and synchronize all devices using an accurate watch/clock that will be used to time the recording intervals of the reference thermometer.
   b. Set the record interval of each thermistor to a short period, (approximately 6 to 30 seconds).
   c. Record the date, sensor serial number, data logger serial number, and analyst's name in a laboratory notebook.
   d. Place the reference thermometer and the continuous monitoring devices in a five-gallon pail or cooler filled ½ full with water that has reached room temperature overnight, or in a controlled-temperature water bath that has reached room temperature (~25°C, 77°F). Make sure the casings of all continuous monitoring devices are completely submerged. Stir the water, just prior to, and during the calibration period to prevent any thermal stratification. Small aquarium circulation pumps (under gravel filters) work well for this application.
   e. After allowing 10 minutes for the continuous monitoring devices to stabilize, begin recording data for a 5-minute interval. Record the time, the reference thermometer temperature, and the continuous monitoring device temperatures measured at the predetermined sampling frequency (e.g., 6 second, 10 second) used during the 5-minute interval. After all readings are completed, calculate the difference between the reference thermometer and each of the continuous monitoring devices for each reading and calculate the mean difference.
   f. Any continuous monitoring devices not operating within their specified accuracy range should be thoroughly scrutinized. If a particular device returns readings that are outside of the manufacturer's accuracy limits, but is still precise, then a correction factor (addition and/or multiplication) can be applied to the data. If units are inaccurate and imprecise, they should not be used.
   g. Using the same water bath, add enough ice to nearly fill the bucket and bring the temperature down to nearly freezing. Stir the ice bath to achieve and maintain a constant water temperature. Place the reference thermometer and the continuous monitoring devices in the water bath or five-gallon pail. Again, make sure that the casings are completely submerged.
   h. Repeat steps 2b-d with ice water bath.
   i. Confirm that thermistor batteries have sufficient charges for the entire monitoring period (will the length of the upcoming field season fit into the life expectancy of the unit's batteries?).

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j. Calibration should be repeated when sensors are retrieved at the end of the sampling season (post-deployment calibration). Repeat steps 2a-f.

Quality Assurance and Quality Control

Precision and Accuracy

Continuous monitoring device accuracy should be ±0.5°C, as measured by pre- and post-calibration checks. A logbook must be kept that documents each unit's serial number, calibration date, test results, and the reference thermometer used.

In addition to laboratory quality control (accuracy) checks, temperature-monitoring equipment should be audited during the field season. The purpose of a field audit is to insure the precision of the data and provide an occasion for corrective action, if needed. A field audit is a comparison between the field sensor and a hand-held NIST-traceable reference thermometer. Reference thermometers used for field audits must meet the same specifications as those used for laboratory calibrations: accuracy of ±0.5°C, resolution of 0.1°C. A minimum of two field temperature audits should be taken during the sampling period — one after deployment when the instrument has reached thermal equilibrium with the environment, and ideally one prior to recovery of the device from the field.

A field audit is performed as follows:

1. Place the reference thermometer in close proximity to the continuous monitoring device.
2. Record the reference thermometer temperature in a field notebook or on the audit sheet for that particular unit.
3. Vemco brand temperature data loggers interrupt data collection when the unit is connected to a computer. With this type of unit, field audit data can only be applied by "post-processing", i.e.; the stored data are downloaded and later compared to audit values. This does not permit on-site corrective action if the sensor is not within accuracy specifications.
4. Data loggers typically set date and time based on the set-up computer's clock. It is important that field personnel synchronize their watches to the computer clock's time. Prior to the field audit, the computer clock should be set to the correct date and time. All continuous monitoring devices are calibrated to the atomic clock via http://nist.time.gov/ . Also available from NIST is a downloadable program that updates your computer clock to with in 0.05 seconds of the atomic clock

Note: Please refer to the current Oregon DEQ Data Quality Matrix (see the following section on Continuous Monitoring Data Quality Assurance and Quality Control or contact the DEQ QA Officer) to identify the accuracy and precision criteria for different Data Quality Levels (OR DEQ, 2004). Temperature sensors used for regulatory purposes must meet Data Quality Level A or B criteria.

Considerations for Sensor Deployment

Temporal Considerations - Sampling Frequency

The time interval between successive temperature readings can be adjusted from every few seconds, to every few hours, to every few days, for most continuous monitoring devices. In most monitoring

activities, the primary objective is to determine the highest temperatures attained during the year. Thus, one of the deciding factors in setting the sampling frequency on a device will be to ensure that the daily maximum temperature is not missed.

The sampling frequency will depend on the monitoring question and the statistic to be calculated from the data. If the 7-day moving average of the daily average is to be calculated, then a less frequent sampling frequency can be used (e.g., 1.2, 1.6, 2.0 hr) (FSP, 1998). However, if the 7-day moving average of the daily maximum is to be calculated, then the daily maximum temperature should be captured. If monitoring data is collected infrequently, the daily maximum temperature is likely to be missed. The sensor should be set to record temperatures **at a maximum of every 1-hour (60 minutes**). The more frequent the monitoring, the more precisely the daily maximum temperature can be characterized. The disadvantage of frequent data collection is reduced number of days of data storage and increased number of data points to be analyzed.

Selection of appropriate sites for monitoring depends on the purpose and monitoring questions being asked. There are two scales of consideration for the appropriate monitoring site:

1. selection of a sample point or location in the stream which provides representative data
2. the broader strategy of selecting sites that can provide useful information to answer the questions being asked.

Spatial Considerations

The simplest and most specific scale is a sampling point on a stream. Here, the focus is on sample collection methods that will reduce variability and maximize representativeness.

Monitoring must record daily maximum at locations which represent average conditions - not pockets of cold water or isolated hot spots. Measurements should be made using a sampling protocol appropriate to indicate the effect to beneficial uses (OCSRI, 1996). Thus, sampling locations should be selected to be representative of the waterbody or stream segment of interest. In order to collect representative temperature data, sampling site selection must minimize the influence of confounding factors, unless the factor is a variable of interest. Some confounding factors include:

- confluence of tributaries
- groundwater inflows
- channel morphology (particularly conditions that create isolated pools or segments)
- springs, wetlands, water withdrawals, effluent discharges, and other hydrologic factors
- beaver ponds and other impoundment

Site Installation

1. All sensors should be placed in the thalweg of riffles to insure a complete mixing of the water and to maintain sufficient water depth for the duration of the sampling window. Alternatively, if riffles are too shallow place the sensor in a pool or glide that exhibits well-mixed conditions. **DO NOT** place the sensor in a deep pool that may stratify during the summer, unless this is the objective of your study. This measure insures that sensors are not selectively placed in cooler areas such as stratified pools, springs, or seeps or in warm, stagnant locations (hot spots), that would misrepresent a stream

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reach's temperature signature. A hand-held thermometer can be used to document sufficient mixing by making frequent measurements horizontally and vertically across. A ***thermal reach*** is a reach with similar (relatively homogenous) riparian and channel conditions for a sufficient distance to allow the stream to reach equilibrium with those conditions. The length of reach required to reach equilibrium will depend on stream size (especially water depth) and morphology (TFW, 1993). A deep, slow moving stream responds more slowly to heat inputs and requires a longer thermal reach, while a shallow, faster moving stream will generally respond faster to changing conditions, indicating a shorter thermal reach. Generally, it takes about 300 meters of similar riparian and channel conditions to establish equilibrium with those conditions in fish-bearing streams. The stream cross-section. If stream temperatures are relatively homogenous (±1-2°C) throughout the cross section during summer low-flow conditions, then sufficient mixing exists.

2. Monitoring devices should be installed such that the temperature sensor is completely submerged, but not in contact with the bottom. Place the sensor near the bottom of the stream by attaching it to a rock, large piece of woody debris, or a stake. Use zip ties, surgical tubing, or aircraft cable to attach the sensor to the bottom substrate. Re-bar or diver's weights can be used if no suitable fastening substrate is available. For non-wadeable streams, the sensor should be placed one meter below the surface, but not in contact with a large thermal mass, such as a bridge abutment or boulder (ODF, 1994). If the monitoring site is not in a heavily visited area, mark the location of the sensor by attaching flagging marked with the gauge number or site ID number to nearby vegetation.
3. Precautions against vandalism, theft, and accidental disturbance should be considered when installing equipment. In areas frequented by the public, it is advisable to secure or camouflage equipment. Visible tethers are not recommended because they attract attention. When equipment cannot be protected from disturbance, an alternative monitoring site should be considered.
4. Install the sensor in a shaded location; canopy cover or some other feature such as large woody debris can provide shade. If no shaded locations are available, then it may be necessary to construct a shade covers for the sensor(s) (e.g., using a section of large diameter plastic pipe.) The intention for this measure is to avoid direct solar warming of the sensor. The intent **is not** to suggest that sensors should be placed only in shaded thermal reaches.
5. Sensors should be located at the downstream end of a thermal reach, to characterize the entire thermal reach, as opposed to local conditions.
6. The number of thermistor units deployed will vary with
    a. drainage area of the watershed,
    b. numbers and sizes of inflow tributaries or other transitions in riparian condition,
    c. changes in elevation, and
    d. proximity to coastal fog zone.

    In all circumstances, a continuous monitoring device should be located as far downstream as surface water flows during the summer. In watersheds with multiple sensors, locate them in a lower/upper or lower/middle/upper distribution.
7. Mark all monitoring site locations on a USGS 1:24,000 topographic map, aerial photo, or GIS map. Clearly show the location of the site with respect to other tributaries entering the stream, e.g., above or below the confluence. Record measured distance to a uniquely distinguishable map feature (i.e.,

road crossing, specific tributary, etc.) Draw a diagram of the monitoring area. Include details such as:

harvest unit boundaries,

a. sensor location and thermal reach length,
b. tributaries with summer flow,
c. description of riparian stand characteristics for each bank,
d. areas where portions of the stream flow become subsurface,
e. beaver pond complexes,
f. roads near the stream,
g. other disturbances to the channel or riparian vegetation (heavy grazing, gold dredging, gravel mining, water withdrawals)

8. Record the serial number of each sensor/data logger combination at each monitoring site. Make an effort to deploy the same sensor/data logger combination at the same site each year.
9. Once a sensor/data logger combination has been deployed at a site, **DO NOT** move the equipment to another location. Adjustments in sensor location may be necessary if the initial location runs dry, and the sensor must be moved to the active, flowing channel. This will necessitate a unique site-id for spatial statistical analysis. Make notes of such relocations in the field notebook or audit sheet.
10. If sensors are used to collect long-term baseline or trend data in specific watersheds, establish fixed-location-monitoring stations so that data sets will be comparable.

Mid-Season Field Audit/Calibration Check

If data downloading is performed in mid-season, this provides an opportunity for a mid-season field audit and calibration check.

Data Verification and Validation

QA procedures must be applied to all continuous monitoring data before data is released from the DEQ Lab. For a more thorough discussion, see the final section of MOMs: Continuous Monitoring Data Quality Assurance and Quality Control.

The data will be converted (from .bin and .asc formats) to a common format (.txt) in preparation for data verification and validation. Note that files must be saved with separate Date, Time, and Temperature "fields" to be properly processed.

Data will require verification and validation because in many cases the data files contained ambient air temperature spikes (most often occurring immediately prior to field deployment and immediately after retrieval from the stream), and any other anomalous data (such as unit malfunctions). A more detailed discussion is presented below.

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Importing and Converting Data Files

The first step in the process of data verification are importing or converting data files into a common format. A set of customized macros (EXCEL™ programs) are used to process and verify each data file. Always check to make sure you are using the latest version of processing utilities, as they are updated every year.

The macros process the data in the following sequence:

1. transfer site identification (site ID) numbers and audit information,
2. transfer and format date/time and temperature data from raw text files,
3. plot temperature vs. date (per month) on a graph, and plot temperature vs. SDMA on a graph
4. create a statistical overview of data
5. copy and save data and audit information to a comma-delimited text (csv) file for verification

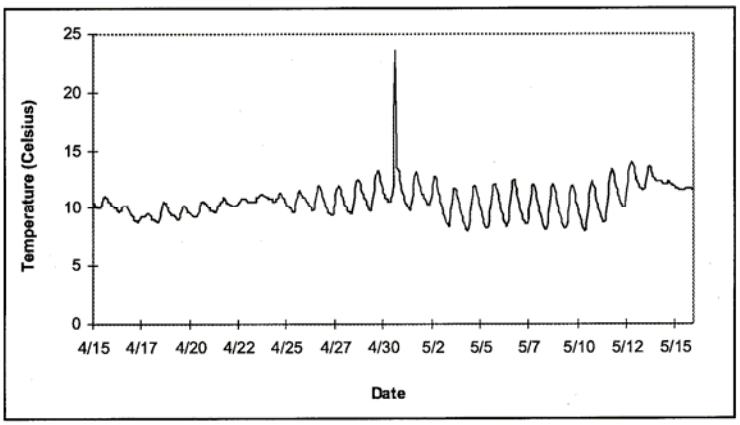
All changes made to data files are recorded and saved at the bottom of the Audit tab of processed files prior to running override macros. Only the validated data are imported into LIMS. For a more thorough discussion, see the section on Continuous Monitoring Data Quality Assurance and Quality Control.

Troubleshooting Data Files

Ambient Air Temperatures

Air temperature spikes are the most common types of errors that are encountered. To find where these errors occurred, (as with all other error types), time versus temperature graphs are generated in EXCEL™ for each site and visually inspected. Stream temperatures, in general, do not fluctuate by more than 10°C diurnally. However, daily fluctuations in air temperature by this amount and greater are common. Below is an example of air temperature readings occurring in the middle of a data set (**Figure 8**).

Figure 8 Air Temperature Spike



Air temperature spikes prior to sensor placement and/or after sensor removal are also detected by visually inspecting the temperature graphs (**Figure 9**). Most often the time of occurrence of ambient air spikes are

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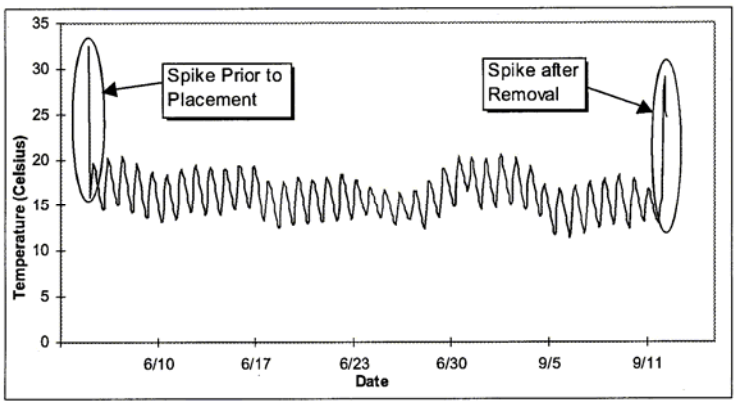
identified by a rapid change in temperature, more rapid than generally occurs in water temperature data; this is typically several degrees Celsius in one or two hours.

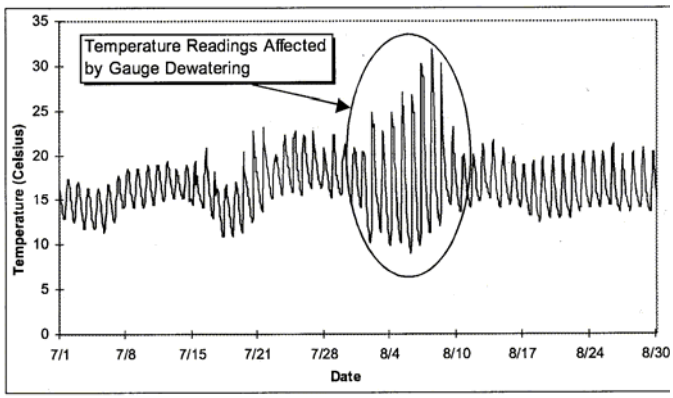
Figure 9: Pre- and Post- Deployment Spikes



Sensor De-watering (Out of Water)

This condition occurs when water levels gradually drop below the sensor as the summer progresses. The temperature sensor is gradually exposed to the air. On the temperature graph, these areas typically have diurnal temperature fluctuations greater than 15°C and often the daily maximum temperatures are above 28°C (**Figure 10**). Note that during the hottest part of the summer, the diurnal temperature fluctuations are greatest; and that during the month of July, anomalous spikes appear in the daily maximum temperature. These are indicators of a sensor that will soon be de-watered (out of water).

Figure 10 Sensor Out of Water

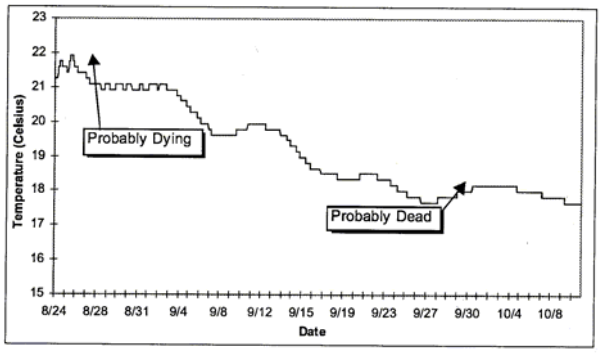


Dead or Dying Batteries

When the charge on temperature sensing device batteries is waning, the unit will begin to record erroneous values. Typically, there will be several consecutive readings (more than five in a row) that will

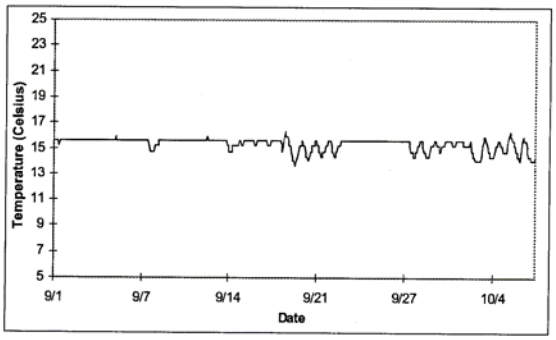
be exactly the same down to the hundredths of a degree. These readings are removed from the data set. Typically, these thermistors display a 'stair-stepping' of values (many readings at the same value, then a sudden jump to another level of readings). Note that the diurnal temperature fluctuations gradually decay (**Figure 11**), until there is a flat line (i.e., no change in temperature value).

Figure 11 Dying Battery



Occasionally, sensors are placed in deep pools that may be influenced by significant groundwater influx (springs). These sites appeared as if a dying battery is the cause of the apparent anomalous readings (**Figure 12**).

Figure 12: Sensor Placed in Deep Pool



Unit Malfunctions

Unit malfunctions are difficult to detect and diagnose. This category of error can apply to any anomalous data sets that cannot be explained by any other error category. Typically, when this type of error occurred, the entire data set is discarded. However, before discarding the data, the data contributor is contacted to confirm a possible unit malfunction. The graph below (**Figure 13**) illustrates significant down-spikes at regular intervals. The readings are not actual water temperatures, but are unexplainable malfunctions with the sensor.

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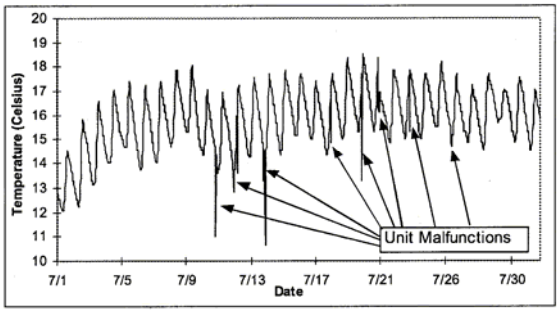
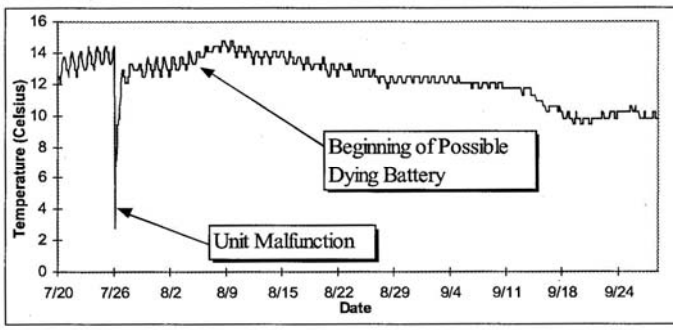
Figure 13 Sensor Malfunction



In the graph below (**Figure 14**), the down-spikes are clearly a unit malfunction. The abnormal fluctuations following the down-spike are problematic. The flattened tops and bottoms indicate either a unit malfunction or a dying battery. However, it is possible that this unit is placed in a deep pool with significant temperature stratification (diurnal temperature fluctuations are smaller than the resolution on the recording device; or the unit is strongly influenced by groundwater input). Where a unit malfunction is suspected, the data contributor should be contacted to determine the most probable source of the problem, or if there are no problem with the device.

Figure 14 Sensor Malfunction



General Rules for Data Removal

During the data verification and validation process the following guidelines are used when removing anomalous data. These guidelines are modified to retain as much data as possible and are discretionary in the hands of the operator.

- Review two (2) days before and after an air temperature spike.
- Review 12 hours of data before and after gauge de-watering spikes.
- Review two (2) days of data before the point where a dying battery is indicated.
- Review two (2) sensor observations before and after a single unit malfunction to determine whether the malfunction was a single, anomalous event or it was symptomatic

of a long-term malfunction.

- If there are several obvious malfunctions, remove two (2) days before the first error, two (2) days after the last error, and all data in between.
- The removal of data should always be noted on field audit sheets (override section and/or comments section)

Discrepancy Logs/Overwriting Files

Use the current data processing utility (Hydrostat) to make corrections to data files. Override instructions are placed at the bottom of the Audit tab of processed files. Overrides are then initiated by running macros within the processing software and are reviewed to ensure that the data was properly modified to reflect the desired deletions or grade changes. See current macro operating procedures for specific instructions on data manipulation.

Data Import

Prior to importing temperature data into LIMS, all changes will be confirmed with the data contributor. If there are no anomalies in a particular data file, the data will be imported directly into the database. If all changes are correct, the data contributor signs the list, and the validated data are imported into the database. If the changes are incorrect, the appropriate changes are made to the data files as per the data contributor's instructions. This process will be reiterated until final reconciliation of discrepancies is reached. Users may access uploaded data via the World Wide Web, on the DEQ Intranet using the LasarFace utility, or by requesting data sets from DEQ.

Once the verification and validation process are completed, the stream temperature data and associated attributes are appended to the state DEQ archival database (LASAR) using current upload procedures.

Calculations

It is recommended that only data that meets quality control requirements be used for statistical analyses. Data are considered Data Quality Level A if the instrument's pre- and post-deployment calibration checks are within ±0.5°C of the NIST-traceable reference thermometer and if the data are bracketed by field audits, which meet the ±1.0°C accuracy criterion.

Seven Day Moving Average (SDMA)

The seven-day moving average of the daily average and the daily maximum can be calculated with most spreadsheet, database, and statistical software. The seven-day moving average of the daily average is simply the sum of seven daily average temperatures divided by seven. The seven-day moving average of the daily maximum is the sum of seven daily maximum temperatures divided by seven. The same is true of the seven-day moving average of the daily minimum.

The Oregon Department of Environmental Quality uses a "centered" version that is calculated as in the following example:

$$\textbf{SMDA} = \frac{10.2+10.5+9.6+9.4+10.0+10.8+10.4}{7}$$

Temperatures in black are daily averages on either side of the moving average being calculated (number in gray).

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UNIDATA PORTABLE DATA LOGGER

Scope and Application

The Unidata STARLOG Portable Data Logger, Model 6003B, is a battery-operated data gathering unit, ideally suited for automatic and continuous data collection at remote, unmanned locations (STARLOG User Manual Supplement 6200, Nov. 7, 1990). Unidata Loggers adapt to a variety of monitoring probes for measuring different environmental parameters, and to a variety of monitoring applications, depending on the type of field data required for a particular study. However, the following restrictions apply:

1. Parameters - Continuous-monitoring equipment is available at the DEQ Lab for measuring Water Depth, Water and Air Temperature, Relative Humidity, and Solar Radiation. There are other sensors/probes available, but DEQ staff only has field experience using the sensors described herein.
2. Deployment Period (logging time) - Loggers are battery-operated and the life of the battery depends on the scan rate and the logging period. See User Manual Supplement #6244, Rev. E, Nov. 7, 1997, Pg. 16-17 for more information on calculating battery life.
3. Water Body Types - Freshwater streams, bays, lakes, and springs. To date, Oregon DEQ has not used Unidata Loggers for saltwater applications, but that option is available.
4. Depth - Depends on the parameter being monitored. DEQ has the following probes in inventory:

Model	Depth Range	Resolution
Model 6508A	0 to 1 meter	4mm
Model 6508B	0 to 2 meters	8mm
Model 6508C	0 to 5 meters	12mm

5. Temperature - The operating ranges of the Model 6507A Temperature Thermistor, Model 6508 Hydrostatic Water Depth/Temperature Probe, and Model 6501 Weather Instrument are as follows:

Model	Operating Range
Model 6508:	Water Temp. -1 to 60°C.
Model 6507A:	Water Temp. –8.9 to 54°C
Model 6501:	Air Temp. –17.8 to +60°C

6. Adequate Protection - Loggers are placed inside weather-resistant enclosures that are mounted on steel pipes driven into the ground at the edge of the waterbody being monitored. The cable end of the water depth/temperature probe is wired to the green field termination strip inside the weatherproof enclosure box, and the sensor/probe is anchored to the substrate of the stream. The weather instruments are attached to the top of the steel-mounting pipe above the weatherproof enclosure box and the cable is wired to the field termination strip.
7. Security – At deployment, the loggers are placed inside the weatherproof enclosures. These enclosures are not locked, but DEQ staff has experienced very few problems related to theft or vandalism. Steps should be taken to select monitoring sites either out of public view, or on private

property with the owner's permission.

8. Accessibility – Should be based on the requirements of the project and the professional judgment of the field staff.
9. Movement - Unidata Loggers are best suited for field applications that call for long monitoring periods.
10. Equilibration Period - Depends on the field parameter being measured.
11. Data Quality Objectives - Data results will not be considered reliable, or be released from the DEQ Lab for general use until they meet the requirements of the Data Quality Objectives outlined in the **Quality Control Criteria** section of this document or that are described in the Quality Assurance Project Plan.

Manufacturers Specifications

Oregon DEQ uses the Unidata STARLOG Portable Data Logger, Model 6003B. A complete description of the Unidata Logger and the probes used by Oregon DEQ is contained in the STARLOG Users Manual, but for the purposes of these QA/QC Procedures, the following is a brief listing of manufacturer's specifications.

MONITORING INSTRUMENTS

Unidata Logger, Model 6003B:

This logger is a battery operated, microprocessor-based data gathering device. It communicates with monitoring probes via the Model 6103C Field Termination Strip.

Operating Rng:	-20 to 60°C
Scan Rate:	0.25 to 15 seconds
Log Rate:	0.25 sec. to 168 Hr.
Memory:	CMOS RAM 32K bytes, expandable to 64K
Clock:	Battery powered, crystal regulated
Analog:	8 Channel, 8-bit successive approx.
Digital:	4 Channel, 4-bit & 8-bit w/pre-scale
Serial:	Bi-directional, synchron. Data/clock
RS-232	Serial, half-duplex, TTL levels, 8 data bits+1 stop bit, no parity, 16 bit check-sum, 300 to 9600 baud
Processor:	8 bit, Intel single chip MPU, type 8748
Connectors:	25 pin 'D' type; INPUT – socket, OUTPUT – plug

Model 6508 Hydrostatic Water Depth Probe:

This probe is designed to provide long-term measurement of water depths from 0 to 5m and water temperature from -8.9 to 54 Degrees C. Probes are sealed, factory calibrated to standard ranges,

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temperature-compensated, and interchangeable (STARLOG Users Manual, Sup. #6217, Rev. B, March 8, 1989, Pg. 1).

Depth Ranges

Model	Depth Range	Resolution
Model 6508A	0 to 1 meter	4mm
Model 6508B	0 to 2 meters	8mm
Model 6508C	0 to 5 meters	12mm

Temperature Output & Input Signals -

Accuracy: +/-1% of range (0 to 50 Degrees C)

Resolution: 0.1% of range (-1 to 40 Degrees C)

Oper. Range: -1.0 to 60°C

Model 6507A Thermistor TempERATURE Probe

This is a Negative Temperature Coefficient (NTC) thermistor used in conjunction with thermistor reference resistors (Model 6104), interchangeable and factory calibrated for two years or more. (STARLOG Users Manual, Sup. #6207, Rev. E.)

Accuracy: +/- 0.2 °C, pre-calibrated

Range: -8.9 to 54°C.

Resolution: 0.5 °C, normal operating range - 8.9 to 35°C

1.0 °C, normal operating range 35 to 54°C

Model 6501 Weather Instruments

Refer to STARLOG Users Manual, Supplement #6206, Rev. L, April 15, 1997, "Weather Instruments" for information on design. Factory specifications for ambient air temperature, solar radiation and relative humidity are:

Ambient Temperature

Calibrated Range: -17.8 to 60 Degrees C

Calibrated Accuracy: +/-0.5 Degrees C

Solar Radiation

Calibrated Range: 0 to 1500 W/sq. m

Calibrated Accuracy: +/-5%

Relative Humidity -

Calibrated Range: 5% RH to 95% RH

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Accuracy: +/-5% over calibrated range

AUDIT INSTRUMENTS

VWR Model 61220-601 Electronic Digital Thermometer

This is a portable electronic thermometer with a solid-state microprocessor and 125 mm thermistor probe for liquids, semi-solids or gas/air. Its dual scales read in Degrees C or F. It operates on 9V battery or 115V AC adapter/re-charger and comes with a NIST traceable calibration certificate and manual.

Range: -40 to 150 Degrees C (-40 to 300 Degrees F)

Accuracy: +/-0.2 Degrees C

Resolution: 0.1 Degrees C

Preventative Maintenance

Preventative maintenance is the process by which preventable malfunctions are identified or determined. Specific operational and maintenance procedures must be followed to maximize proper functioning in the field. They include the following:

- Sensor Care – When not in use, all Unidata Loggers and related field equipment should be cleaned and stored in a safe, dry storage area.
- Battery Voltage - Battery life is dependent on the scan rate and log rate programmed into the monitoring scheme. Information about power supply and battery packs for Unidata Loggers can be found in Section 4 of Supplement 6244, Rev. E, November 7, 1997 of the STARLOG Users Manual.

Programming

Prior to field deployment, a Unidata Logger must be programmed with a "Scheme". The program scheme is the definition of the data logging project, and includes the scheme name and title, a data file unload directory, scan rate and log rate, instrumentation (probe types), and the data output file details. The STARLOG Users Manual # 6203, Rev. B, April 3, 1998 contains complete details for creating schemes and programming them into the Logger. For the purposes of these procedures, the following is a brief outline of that process.

Instructions for Creating Computer Schemes for Unidata Continuous Loggers Using Starlog Software Version 3.08, Rev. D

1. Turn on the computer (Laptop or Desktop). Click on the Starlog Icon in the Windows 95 Screen.
2. The first screen to appear is titled "**Open A Scheme**" and lists 4 Demo schemes, one of which is called Test Scheme #1. This scheme is an example scheme for the Model 6003B Unidata Logger with #6507 Wtr. Depth/Temp probe and # 6501 BU Weather Instrument. Review Test Scheme #1 to become familiar with how to write new schemes for Model 6003B Loggers.

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3. Hit "**Esc**". The basic Starlog Software screen should now be open and the menu bar at the top of the window should read "System Panel Configure Window Help". Select "**System**", then "**Scheme Editor**". Hit "**Enter**".

4. The Screen Editor window has a menu bar that reads "**Scheme Window Help**". Select "**Scheme**", then "**Create**" from the small menu box that is now open. Hit "**Enter**".

5. The next screen to open is "Hardware" window. Use the down arrow key to access the hardware list showing the complete list of Logger Models. Select the appropriate Logger type; for example: **6003 Unidata Logger Model B 64K**. Hit "**Enter**", then "**Esc**" to return to the Scheme Editor window.

6. Select "**Alt-W**" to open the Window Menu Bar, then select "**General**". Select "**Description**" and then type in a description of the scheme you are creating; for example: "Logger 4467 Practice". Select "**Unload Comment**" and put an "X" in the brackets [X}. Hit "**Alt-F3**" to save.

7. At the Window box, select "**Communications**" and then hit "**Enter**". Check the items shown in the box titled "Communications" and make sure that the correct serial port is Com1, and the Baud rate is 9600. Hit "**Alt-F3**" to save.

8. Hit "**Alt-W**" to open the Window box and highlight "Instruments", then "**Install**". Use arrow keys to move up and down through the list of instruments (probes):

   8a. Select "**6508-A Hydrostatic Water Depth & Temp Probe-1m**", then "**Enter**".

   8b. Select "**Alt-W**", "**Instruments**", and "**Install**". Arrow down **to "6501-BU Weather Instrument -TGH**", then "**Enter**".

9. The window titled "Instruments" should now list two probes, and editing of each probe can be done at this point.

10. Highlight the first probe listed, i.e. "**6508A-Hydrostatic Water Depth & Temp Probe**", hit "**Enter**". Under the heading "Transducers" highlight Item No. 1 "**Water Depth**", then hit "**Enter**". In the screen now showing, highlight "**Channel**" and enter the correct channel. The default channel for water depth is **a0**, which is correct. Click on OK. Highlight Item No. 2 "**Red Thermistor**" under "Transducers", hit "**Enter**". Highlight "**Channel**" and enter the correct channel for water temperature, which is **a1.** Hit "**Enter**" and "**Enter**" to get back to the Instruments window, then highlight the second probe in the Instruments box, which should be **6501-BU/T Weather Instrument**. Select each item under "Transducers" and enter the correct channel for each item. The complete list of channels for both probes is as follows

Sensor Model	Transducer	Channel	Terminal	Wire Color
6508A Probe	Battery	a6	17	Red
	Water Temp	a7	18	Yellow
	Water Depth	a5	24	Blue
6501	Battery	a6	16	Red
	Air Temperature	a2	33	Yellow

Sensor Model	Transducer	Channel	Terminal	Wire Color
	Solar Radiation	a4	27	Blue
	Relative Humidity	a3	30	Black

11. "**Esc**" back to the Instruments window and hit "**Alt-F3**" to save, then "**Alt-W**". Highlight "**Program 1**" in menu box. All settings in the Program 1 box should be correct, except "**Log Interval**". Highlight "**Log Interval**" and change to desired interval, i.e. 000:01:00.00. Hit **Alt-F3**.
12. Highlight ""**Log Buffer 1**", hit "**Enter**". Select "**View**", then "**Enter**". Make sure that the list of channels for each water quality parameter to be monitored is correct. Example:
    a6 Battery
    a7 Water Temperature
    a5 Water Depth
    a2 Air Temp.
    a4 Solar Radiation
    a3 Rel. Humidity
13. Use a mouse (or Track Ball) to move between lines and columns; Put "X" in brackets [X]. Hit **Alt-F3** to save.
14. Hit "**Alt-S**" for scheme menu box, then select "**Save**" to save scheme. Hit **Alt-X** to get back to the Starlog Software window.
15. Select "**Panel**", then "**Open**". Highlight the correct scheme from the list shown, hit "**Enter**". The Scheme Control Panel is now open. At this point, connect the Logger to the computer and the probe cable wires to the green termination strip mounted next to the Logger inside the weatherproof box. Refer to the wiring directions listed above in these instructions.
16. Connect the computer to the Logger via the connecting cable. Attach the small plug end of the cable to the computer Serial Port 1, and the large plug end of the cable to the port on the bottom of the Logger front labeled "Computer".
17. From the Starlog software window, highlight "**Panel**", then "**Open**". Highlight the correct scheme from the list and hit "**Enter**". The Scheme Control Panel should now be open. Plug the gray strap with the blue plug end into the port at the top of the Logger front. Select "**Program Logger with Scheme",** then "Enter".

Calibration/Accuracy Checks

Model 6508 Hydrostatic Water Depth Probes, Model 6507A Thermistor Temperature Probes and Model 6501 Weather Instruments are factory calibrated and, when properly written into the logging scheme, no further calibration is necessary. The standard DEQ Lab water bath accuracy check should be conducted on the water temperature probes prior to field deployment.

Predeployment

The pre-deployment check is a list of procedural items designed to insure that continuous monitoring equipment is ready for field deployment.

1. Do batteries have sufficient voltage? Select "Scheme Test Mode" from User Menu to check battery life. Change battery pack when voltage drops below 5V.
2. Has the logging scheme been written and stored in the logger memory?
3. Have previously stored data been erased from the logger memory? Loading a new scheme into Logger will automatically erase previously stored data.
4. Have all necessary probe calibrations been done?
5. D.O. and pH probes must be calibrated before field installation.
6. Have proper record-keeping procedures been developed? Use separate data sheet for each Logger.
7. Have the monitoring sites been identified and road and trail access been mapped?

Deployment

Field deployment of Unidata loggers is the process by which the monitoring equipment is installed at a predetermined location on the waterbody being monitored. Ideally, monitoring sites have been identified based on their potential to provide quality data, accessibility, staff safety and equipment security. The process for installing Unidata loggers in the field is straightforward. A quick checklist of necessary equipment and tools is as follows:

Material List:

- ft. Galv. steel pipe
- Weather-proof enclosure and mounting bracket
- Unidata Logger and probes
- 2-3 ft. steel rebar or 12” galv. steel spikes
- Crescent and/or socket wrenches and ratchet
- Flat-head and Phillips screw drivers
- Wire cutters, pliers, grip-lock pliers
- Small sledge hammer, pipe driver
- Electrical tape, Duct tape
- Cable tie straps
- Laptop computer, Logger-PC Interface & cable
- Field data sheets
- NIST traceable thermometer, water depth staff

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Installation procedures:

1. Drive steel pipe into ground at edge of the water body.
2. Mount weather-resistant enclosure onto steel pipe.
3. Place Logger and Field Termination Strip inside enclosure and install colored probe wires to FTS terminals.
4. Secure Depth/Temp. sensor to stream bottom and mount weather instrument to steel pipe.
5. Connect computer to Logger w/Logger-PC interface/cable.
6. Load logging scheme into Logger.
7. Check Scheme Test Mode screen to verify that Logger is operating properly.
8. Take initial field parameter measurements (battery life, date/time, water depth & temp., air temp., stream flow) and record data on field data sheets.
9. Install enclosure cover.

Audit Measurements

The DEQ Quality Assurance/Quality Control Program requires that field audit measurements be taken in conjunction with the use of continuous monitoring equipment. Field audits are conducted to verify that the loggers are operating properly, to determine the quality of the continuous monitoring data, and to gather data that can be used to re-calibrate the instruments when necessary.

Audit Procedures

1. Unidata Loggers generate large quantities of data and the field audits must be conducted at a frequency sufficient to verify the quality of data being produced. Audit frequency depends on the requirements of the project plan, but also on the logistics of the project. A minimum of three field audit measurements are to be taken in conjunction with each Unidata Logger deployment: 1) Just after initial deployment; 2) sometime mid-season; 3) Just before the logger is retrieved from the field.
2. A field audit is the process by which comparison data is produced independently of the Unidata Logger, and can be instantly compared to Logger readings.
3. Specific audit procedures include the following:
   a. Take water depth measurement with certified depth gage in the water column from the tip of the depth sensor to the water surface.
   b. Take water/air temperatures using an NIST traceable thermometer.
   c. Take stream discharge measurement at closest possible cross-section to Logger depth probe.
   d. Compare audit results to instantaneous Logger readings shown in the Scheme Test Mode and record results on field data sheets.
4. DEQ has acquired probes designed to measure relative humidity and solar radiation, but audit procedures for these instruments have not been developed. Until these procedures are developed,

all Logger data on relative humidity and solar radiation will be considered as estimates.

In general, field audits are to be conducted according to DEQ Laboratory Water Monitoring and Assessment Methods of Operations Manual (MOMs). Field data sheets are to be completed according to standard DEQ procedures.

Data Quality Criteria

With each field audit, it is necessary to recognize the variables or factors that influence the quality of audit data. The two most important of these include the accuracy and precision of the loggers and the accuracy and precision of the audit sampling procedure and equipment. To minimize sampling error, it is critical that strict adherence to established sampling guidelines be maintained during each audit. Equipment for measuring water and air temperature is to be NIST traceable, meters for measuring pH are to be properly calibrated, and whenever possible the same measuring devises should be used for all audits required for a given project.

Laboratory staff has agreed that the criteria for establishing appropriate levels of confidence for audit data must be based on a large set of audit/logger comparison values. The assumption is that a large data set of comparison values more clearly indicates that point at which continuous monitoring data can be considered acceptable or not acceptable. See the Data Quality Matrix (in the Quality Assurance section of MOMs, also available from the DEQ Laboratory QA Officer) for accuracy and precision criteria used to assign data quality levels to continuous monitoring results (OR DEQ, 2004).

Data Management

QA procedures must be applied to all continuous monitoring data before data is released from the DEQ Lab. For a more thorough discussion, see the final section of MOMs: Continuous Monitoring Data Quality Assurance and Quality Control.

In summary, individual field data sheets are to be completed for each Data Logger, and must include field audit measurements for each parameter and the comparison values from the Logger. Data sheets from each Logger will be assigned a test (DLOGR) in the LIMS system and staff is expected to follow standard laboratory sign-off procedures for release of data. The standard QA/QC DATA spreadsheet program (QAQCDATA.WQ1) contains the format for analyzing field audit results. This program compares the difference between field audit values and the Logger readings to the percentage range of acceptable limits. All data falling outside these limits will be eliminated from the data file. A QA report will be generated for each data file; copies of edited data files will be forwarded to the Lab Sample Tracker for Sampling Event release; and data files will be arranged in a STORET-ready format and uploaded to the STORET database.

References

Oregon DEQ, 1994. HYDROLAB DataSonde 2 & 3 Quality Assurance/Quality Control Procedures. Water Quality Monitoring Section, Oregon DEQ Laboratory, Portland, OR.

Oregon DEQ, February 2004. Data Quality Matrix Version 3.0, DEQ04-LAB-0003-GD, Oregon DEQ Laboratory, Portland, Oregon.

Unidata Portable Data Logger

UNIDATA Corp., 1998. STARLOG System User's Manual, No.6245, Revision E. UNIDATA Corp.

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DATASONDES

Scope and Application

Datasondes, including the YSI 6920 Multi-Parameter Water Quality Monitor (Figure DS-1) and the Hydrolab DataSonde 2 (DS2) and 3 (DS3) (Figure DS-2), are on-line transmitters of *in-situ* temperature, pH, dissolved oxygen, conductivity, salinity and depth. These instruments can be used for profiling, sampling, or long term monitoring (both on-line and unattended).

Figure DS-1: YSI 6920 Multi-Parameter Water Quality Monitor

Figure DS-2: Hydrolab DataSonde 3 with Internal Battery Pack

At present, the DEQ recommends specific and limited applications of these instruments. Those applications involve using them in the unattended mode with the following restrictions:

- Parameters - Datasondes are available from the DEQ Laboratory Water Monitoring and Assessment Sections for measuring dissolved oxygen, pH, conductivity, temperature and depth.
- Deployment period (logging time) - Minimum of two hours to a maximum recommended five working days (Monday AM to Friday PM). Deployment period may be extended in clean waters where probe-fouling algal growth and sedimentation are minimal.
- Water body types - Fresh or saltwater influenced streams, bays, lakes, springs. Wastewater mixing zones and limited effluent monitoring (requires special industrial application probes).
- Depth - Minimum of six inches, maximum depth of 61 meters (dependent on unit type and probes used.).

- Temperature - Operating temperature is from -5 to 45 °C.
- Adequate protection – The datasonde should be positioned so that the unit is not at risk of damage due to floating debris (downstream side of bridge preferred), deep deposits of sediment (sand or gravel following a rainstorm), and water bodies prone to icing over.
- Security – The datasonde will be properly anchored (cable ties) and/or secured (aircraft cable and lock via the bail). Markers should also be such as to not attract attention (e.g. vandals).
- Audit frequency – Data quality objectives (DQOs) should define audit frequency. Generally, datasondes will be deployed so that a minimum of one audit each day can be performed. Please see Methods, Step 5, Audit Measurements for details.
- Movement – A datasonde may be repositioned during a given deployment if proper handling and auditing procedures are followed. It is recommended that movement of a datasonde be kept to a minimum of once a week unless specific requirements of the study require changes in location.
- Equilibration period - The dissolved oxygen and pH probes require some equilibration time, it is therefore recommended that no data be retained for these parameters for a minimum of one hour following deployment.
- Data Quality Objectives - Once a datasonde has been deployed and the data downloaded, the data results will not be considered releasable (to program staff or a database) until it fulfills the DQOs as outlined below (see Data Quality Criteria in the Calculations and Data Management Section).

Equipment and Supplies

Manufacturers Specifications

Datasonde specifications for range, accuracy and resolution are summarized in **Table 1**for the parameters of concern. It is important to note the differences between accuracy and resolution—accuracy is the difference between the system reading and the "true" value, while resolution specifies the smallest unit division that a system can display.

Additional Hydrolab parameter specifications and qualifications are found in **Table 2**. Included in this table are the instrument's sensor types, compensations required, calibration requirements, response time, and stability. Hydrolab includes as part of its operator's manual a thorough discussion of performance, accuracy, uncertainty, error, resolution, precision and repeatability. For definitions, please see the attached Glossary.

Table 1 Datasonde Parameter Specifications.

Parameter	Range	Accuracy	Resolution
Hydrolab DataSonde 3			
Temperature	-5 to 50 °C	±0.15 °C	0.01 °C
Conductivity	0 to 100 mmhos/cm	±1% of range	4 digits
pH	0 to 14 units	±0.2 units	0.01 unit
Dissolved Oxygen	0 to 20 mg/l	±0.2 mg/l	0.01 mg/l
YSI 6920 Multi-Parameter Water Quality Monitor			
Temperature	-5 to 45 °C	±0.15 °C	0.01 °C
Conductivity	0 to 100 mmhos/cm	±0.5% of reading +0.001 mmhos/cm	0.001 to 0.1 mmhos/cm (range dependent)
pH (LIS)	2 to 12 units	±0.2 units	0.01 unit
Dissolved Oxygen	0 to 50 mg/l	±0.2 mg/l (for 0 to 20 mg/l)	0.01 mg/l
Depth-Medium	0 to 200 ft (61 m)	±0.4 ft (0.12 m)	0.001 ft (0.001 m)

Table 2 Additional Hydrolab parameter specifications and qualifications

Parameter	**Sensor Type**	**Compen-sations**	**Calibration**	**Response Time**	**Stability***
Temperature	thermistor	none required	none required	< 1 minute	three years
Conductivity	6 electrode cell	automatic for temp. (25°C)	KCl or seawater standards	< 1 minute	six months
pH	glass pH; re-buildable or low ionic strength reference electrode	automatic for temperature	pH 7 buffer, plus one slope buffer	<1 minute	one month

Parameter	**Sensor Type**	**Compen-sations**	**Calibration**	**Response Time**	**Stability***
Dissolved Oxygen	rebuildable polarographic; 1-mil Teflon™ or LoFlow™	automatic for temp & salinity	saturated air, Winkler, or saturated water	< 1 minute	one month

* Stability is based on an analysis of the sensor electronics and not direct *in-situ* testing.

For more detail please see the Hydrolab Manual, Appendix 2: Performance Manual for Water Quality Instrumentation.

Preventative Maintenance

Preventative maintenance is the process by which preventable malfunctions are identified or determined. Certain maintenance and operational procedures MUST be followed to maximize proper equipment performance in the field. All maintenance should be recorded in the datasonde's logbook with the date the maintenance was performed and the initials of the technician. The following are critical procedures that must be followed when deploying a datasonde.

Sensor Care

Whenever the datasonde is not deployed, use the calibration cup or the storage cup to protect the sensors from damage, and especially from drying out. For YSI datasondes, the storage vessel should be filled with enough water to provide moist air without submerging the probes. The storage vessel should be tightened down on the datasonde to prevent evaporation. Hydrolab datasonde probes should be submerged in tap water for storage. Fill the calibration cup with enough water to cover the probes and screw the cup on the datasonde tight enough to prevent leaking. Reference electrodes for LIS pH probes should be soaked in saturated KCl filled rubber caps. After any type of sensor service, Hydrolab recommends that the probes rest in tap water overnight.

Remarks Concerning Sensor Preparation

Sensor preparation is probably the most important action you can take to maintain or improve the quality of your field measurements. A contaminated, worn-out, or damaged sensor simply will not produce a reliable reading. It is well worth your time to set up a routine in which all sensors are serviced frequently and then allowed to rest in tap water overnight before calibration.

Calibration

For each parameter to be measured in-situ, the appropriate calibration procedure must be followed. The only exception is temperature because of the unvarying nature of the temperature sensor and its conditioning circuitry. See the following discussion in **Calibration and Standardization**.

Battery Voltage

A battery check should be the first step of any calibration/deployment procedure. The YSI datasonde operates on eight AA-size batteries located inside the datasonde. Depending on the sensor configuration, the eight AA-size batteries should last approximately 30 days at 15 minute logging intervals. Hydrolabs operate using a submersible Internal Battery Pack (IBP) of 12 C-size batteries. Once the IBP is at 9 volts it is too low for another logging run and the batteries in the IBP must be changed.

Deployment Equipment and Supplies Checklist

- Datasonde, battery pack (DS3 only) & storage cup
- Carrying case
- Datasonde unit log book
- pH reference probe cap and storage solution
- DO membrane kit
- Aircraft cable, padlocks and key, crimps and crimping tool
- Cable ties, large
- Cable cutters
- NIST traceable thermometer
- Winkler titration kit and BOD bottles
- pH meter(s) – Sargent-Welch model PBL pH meter; Beckman Model o11 and o21 pH meter, or comparable meter
- Conductivity meter - YSI Model 33 S-C-T meter; YSI Model 30 meter, or comparable meter
- Field data sheets/log book and pencils
- Laptop computer and/or YSI 610-DM, 650 MDS (YSI only), DataSonde battery and cables
- Extra batteries
- P-poly bottle

Calibration and Standardization

Before each field deployment DO, pH, and conductivity probes must pass calibration tests. Because YSI and Hydrolab supply comprehensive operator's manuals that include sections (with instructions) for calibration procedures, only abbreviated portions of those sections are included as Appendices A and B to these QA/QC procedures.

All calibration and standardization procedures must be recorded in the unit's datasonde logbook along with the date and initials of the technician who performed the calibration.

Methods

Deployment of a datasonde for monitoring involves five steps:

1. Enabling the datasonde to measure the parameters of interest.
2. Pre-deployment check to ensure all systems are set up and capable of completing the monitoring
3. Programming the unit to record what you want and when
4. Deployment of the datasonde into the medium to be monitored
5. Audit measurements recorded to assure the quality of data
6. Recovery to collect the data recorded during the monitoring event.

To set up a datasonde for logging see the unit's operating manual for complete instructions, below is an abbreviated version for power users. Bolded items are actual keystrokes or menu selections.

Step 1: Enabling Parameters

Hydrolab

Type **P** from the main menu. Select the parameters of interest. Usually this will consist of **p**H, Specific **C**onductance, D**O**, and **B**attery. Time and temperature cannot be disabled. Enable each parameter, one parameter at a time, by typing **E** (enable) or **D** (disable) if certain parameters are not desired.

YSI

From the PC6000 main menu select **Sonde** to enter the Sonde menu. From the Sonde menu select **7-Sensor** to call up the list of available sensors. To toggle between enabled and disabled, simply press the number shown next to the corresponding probe. A '*' indicates that the sensor is enabled.

Step 2: Pre-deployment

Pre-deployment check is a redundant method whereby specific procedural items are reviewed to insure that an instrument is ready for field deployment.

- Are batteries of sufficient voltage?
- Are correct parameters enabled?
- Has the previously stored data been dumped (saved to disk) and/or erased? Is there room for more data?
- Has the unit passed calibration? DO and pH probes must be calibrated before field deployment.
- Is the unit operating at the real date and time?
- Is the unit programmed with proper logging instructions? To launch a YSI 6920 you

must select **C-Start logging** in order for it to accept your logging instructions.

- Have proper record-keeping procedures been developed? Use a separate data sheet/log book for each unit.
- Is the file name such that it can be clearly identified even if truncated to 8 characters?

Once all of these checks have been accomplished, the datasonde is ready for deployment.

Step 3: Programming the unit to record what you want and when

Hydrolab

Before setting up a logging run insure that the status of the Buzzer, Stirrer, and enabled Parameters are correct before you set up the logging run. In logging menu type **S** and:

1. enter log file name: **SILVERMZ.JUL** (example)
2. enter starting date(MMDDYY): **071293**
3. enter starting time(HHMMSS): **120100** (using 24-hour clock)
4. enter stopping date(MMDDYY): **071693**
5. enter stopping time(HHMMSS): **120100** (using 24-hour clock)
6. enter interval (HHMMSS): **001500**
7. enable warm-up? Type **Y** (no DO-pH polarizing batteries or stirrer installed) or **N** (DO-pH polarizing batteries installed)
8. record all information in the datasonde's log book including the date and your initials

YSI

Unattended deployment setup is accessed by selecting **Sonde** from the PC6000 menu;**1-Run** from the Sonde menu; and **2-Unattended sample** to access the Unattended setup menu. An example is shown below.

```
--------------Unattended setup-------------
1-Interval=00:15:00
2-Start date=07/14/01
3-Start time=06:01:00
4-Duration days=5
5-File=NUM_LARA
6-Site=Steamboat Cr at mouth
7-Bat volts: 9.1
8-Bat life 21.2 days
```

Datasondes

```
9-Free mem 18.9 days
A-1st sample in 8.10 minutes
B-View prams to log
C-Start Logging
```

First, verify that the current time and date are correct on the display to ensure your unit starts recording when you intend it to. If the time is not correct, then you may correct the time by going to **4-Status** or **5-System** from the main menu.

1. Begin the datasonde setup by specifying item numbers 1 through 5 shown above. To do this select the number of the item you wish to set and enter the appropriate value. For example, to set the recording intervals select **1-Interval** and type in **00:15:00** for a 15-minute interval. Follow the same procedure for Start date, Start time, Duration days, and File. Date format is in MM/DD/YY and time is in 24-hour format. Entering a site description is optional.
   Please note that the default value for Duration days is 365 days! It is important to re-set this value to the appropriate length of your study so there will be sufficient memory available for other projects. (The only way to delete a file is to delete ALL files.) You can stop the unattended sampling manually after the study.

   A file name should be selected that will clearly identify the file from other datasondes which may be deployed in the same stream on the same dates.
2. After setting up the timing and file information, press **B-View params to log** to view the parameters set to log. If the parameters you wish to collect are not there, return to the Sonde setup to enable sensors. DO mg/L and Specific Conductance will not be listed because these parameters are calculated from DO %sat, Temp and Cond, and from Cond and Temp, respectively.
3. The datasonde software will then calculate the expected battery life and memory space available in days. Do not start the logging unless these values are longer than the time you intend to have the datasondes deployed.
4. To start the sampling regime, select **C-Start logging**. The next screen will ask you if you are sure. If you are sure, or are at least pretty sure you are sure, then press **1-Yes**. The next screen shows you the logging information from the "Unattended setup" menu so you can re-assure yourself that you really wanted to start logging. If there is an error, you may stop the logging from this menu.
5. Record all information in the datasonde's logbook including the date and your initials.

Step 4: Deployment

Field Deployment of datasondes is a task that involves on the spot evaluation of numerous site-specific factors. First factor in determining whether to deploy a datasonde is, "Does it present any risk to the person deploying the unit?" These datasondes are used in locations that are inherently dangerous and unpredictable, so it is always at the discretion of the field person to decide NOT to deploy a datasonde if they feel that to do so would endanger them in any way. It is therefore important to anticipate changing weather patterns, tides, dam releases, human activity and specific stream conditions prior to deployment of any datasonde.

Typical deployment scenarios involve the placement of datasondes in small wadeable streams with velocities from one to three feet per second. In these situations, it is necessary to find an appropriate structure to which a unit can be anchored. Appropriate structures would be items such as bridge abutments, large sections of trees or root masses found underwater, concrete blocks, fence posts, anything that is likely to remain stationary throughout the logging period and will not interfere with water quality measurements.

It is recommended that each datasonde be secured by running an aircraft cable through the bail and locking it to an object that ensures its security (tree, bridge, etc.). Actual positioning of the datasonde to ensure adequate stream flow and orientation can be accomplished by using large cable ties. It is recommended that a standard of one-meter depth be obtained when practical.

FIELD SAFETY: Wading

- No datasonde deployment is worth endangering your self or co-workers. When wading always work with a partner and follow these guidelines.
- Wear personal flotation devices when wading in streams with depths over your chest.
- Wear appropriate foot wear and move slowly checking for unstable substrate or unexpected holes. A wading rod can be used to help assess streambed conditions.
- Use caution when wading in streams with swift current. As you get deeper your ability to keep a grip on slick substrate will be reduced and you may be pushed off your feet by slower velocities. Even shallow water at high velocities can be dangers. Do not attempt to wade a stream for which values of depth multiplied by velocity equal or exceed 10 ft^2/sec.
- Avoid hip boots that are tight around the ankles and waders that are tight around the chest—these may be difficult to remove in an emergency. Be aware of the possibility of slipping and going underwater (feet up, head down) while wearing them. Wear a hip belt with waders to help prevent filling the waders with water.
- Watch for changes in river stage, especially when working downstream from a control structure. If working directly below a dam, contact the gate operator before entering the stream.
- Watch for sand channels that can shift under foot and become quicksand.
- See the “Working On or Near Water” JSA for further information.

The actual location of the datasonde should be convenient and accessible for repeated audit measurements throughout its deployment period.

Step 5: Audit measurements

PROCEDURES

Comparison of datasonde measurements with measurements made with independent instrumentation is a necessary component of any datasonde quality assurance program. These independent field measurements, called audits, verify the representativeness of datasonde values during deployment conditions. Field audits are quality control procedures used to:

1. ensure the datasonde is generally functioning properly,
2. determine if any drift is occurring,
3. provide the opportunity to recalibrate or replace the probe or datasonde if problems are found, and
4. document data quality.

Frequent audits increase the potential for identifying and correcting malfunctioning datasondes early enough to assure a useful dataset is available at the end of the deployment, and minimize the amount of data of unacceptable quality if a datasonde develops problems that are determined after retrieval.

It is important when conducting a field audit on a datasonde that every effort be made to collect samples for independent analysis that are representative of the water surrounding the datasonde's probes. The procedures listed below should be followed to obtain the most representative audit sample.

<u>In-stream portion</u>

1. Recommended time for sampling is within a five-minute period following the most recent logging time. For example, if a unit logs at 1530, an audit should be done from 1530 to 1535. (If debris clearing is to be performed while at the site, operator must be cognizant of the time, making sure not to disturb the datasonde while unattended reading is logged)
2. A P-poly ("basic" sample) bottle will be filled as close as possible to the datasonde probes, without interfering with the datasonde itself.
3. A dissolved oxygen bottle will also be filled adjacent to the datasonde, with care to not unduly aerate the sample.
4. Finally, a NIST-traceable digital thermometer will be placed as near as possible to the datasonde thermistor and be allowed to equilibrate and stabilize to the stream temperature.

<u>Field measurements</u>

All field measurements will be performed using Laboratory Standard Operating Procedures (SOPs) and the WA Section Methods of Operations Manual (MOMs).

1. pH will be measured using an aliquot of the Basic poly water volume and a field pH meter. The pH meter must be calibrated and verified against standards in the laboratory.
2. Conductivity will be measured in the P-poly bottle using an YSI SCT meter that has passed laboratory QA checks.
3. Dissolved oxygen will be determined using the standard Winkler titration used in the field.

All field data will be entered onto an ODEQ data collection sheet. This will initiate the LIMS paperwork required to track the associated data through the laboratory.

FREQUENCY

DQO's should define audit frequency, which should be documented in a Quality Assurance Project Plan. Datasonde deployments at DEQ are generally related to short term (3-5 day) deployments that provide the data for development of TMDL's where the quality of the data and the value of a complete set of data warrant increased diligence in auditing. Daily audits allow the field team to identify and correct malfunctioning equipment and quantify more accurately in time when the meter began to fail. Experience has been the driver for selecting daily audits whenever possible. Field experience shows that if the waterbody has unusual variations of dissolved oxygen or pH, or if the water is highly degraded, then twice-a-day audits may be necessary. Deviations to audit frequency should be made only with section manager approval and be authorized to the extent possible prior to deployment.

USGS audits at a less frequent rate according to guidelines published on their web page.

> "Maintenance frequency generally is governed by the fouling rate of the sensors, and this rate varies by sensor type, hydrologic environment, and season. The performance of temperature and specific conductance sensors tends to be less affected by fouling, whereas the dissolved oxygen, pH, and turbidity sensors are more prone to fouling. For stations with critical data-quality objectives, service intervals may be weekly or more often. Monitoring sites with nutrient-enriched waters and moderate to high temperatures may require service intervals as frequently as every third day. In cases of severe environmental fouling or remote locations, the use of an observer for servicing the water-quality monitor should be considered. In addition to fouling problems, physical disruptions (such as pump failure, recording equipment malfunction, sedimentation, electrical disruption, debris, ice, or vandalism) also may require additional site visits."
> (page 13 of http://pubs.usgs.gov/tm/2006/tm1D3//pdf/TM1D3.pdf)

Step 6: Data recovery

To recover data from a datasonde see the Hydrolab Operating Manual or YSI Instruction and Service Manual for complete instructions. Below is an abbreviated version for power users. Bolded items are actual keystrokes.

Hydrolab

1. Under the Main menu, type **L** to access the Logging menu.
2. Under the **L**ogging menu: Type **D <CR>** to access the data Dump (recovery) mode.
3. Select the number of the file that you wish to dump and **<CR>** to choose either **P**rinter ready or **S**preadsheet importable. Select appropriate one. You will then get a choice between:
   - **S**etup variables and calibration,
   - **F**ollow variable and calibration changes,
   - **C**urrent variables and calibration,
   - or **Esc** or **Ctrl X** to cancel. See manual for instructions.

Printer Dump

If you have selected **P**rinter ready after **S**, **F**, or **C**, then select:

- **N**o statistics,
- **D**aily statistics,
- **T**otal statistics,
- **B**oth daily and total statistics,
- or **Esc** or **Ctrl X** to cancel. See manual for instructions.

Then activate printer by hitting any key.

Spreadsheet Importable

If you have selected **S**preadsheet importable after **S**, **F**, or **C**, then your prompt will be:

- Starting XMODEM Transfer....
- Give file the name for this data.

Erasing Files

Dumping a file does not erase that file; you must purposely erase a file to regain the use of memory space occupied by that file.

1. Select **E** to get file directory.
2. Type in the number of the file you wish to erase.
3. If you are sure, at the prompt type **Y**.

YSI-data recovery

To retrieve data from a YSI datasonde you may download it onto your PC as follows.

1. Under the main PC6000 menu select **Sonde** to connect to the YSI 6920 Monitor.

2. From the Sonde directory press **3-File** to enter the file menu.
3. Press **2-Upload** to view the file list in memory.
4. Enter the number of the file you wish to retrieve.
5. A "Time Window" will appear giving you the option to select portions of the data to retrieve. Enter **1-Proceed** to download all the data from the file.
6. The "File Type" window will then appear. Three formats for upload are available—PC6000, Comma & ' ' (space) Delimited, and ASCII text—select **3-ASCII text** for your file format.

Data Management

It is extremely important that all continuous monitoring data go through the same rigorous quality assurance/control procedures to insure correctness, consistency, standardization, proper record keeping, and data storage. For a more thorough discussion, see the final section of MOMs: Continuous Monitoring Data Quality Assurance and Quality Control.

For each deployment of a datasonde or group of datasondes for a particular study, a Sampling Event number in LIMS will be assigned. Each individual datasonde will be assigned a test (Water Quality continuous monitoring report) in LIMS and will then be required to follow the established sign-off procedure to release the Sampling Event. For example, three datasondes are deployed as part of a TMDL study. Once the deployment is over, the field person will give the Sample Tracker a data sheet with the entire audit data recorded. Tracker will assign one Sampling Event number and three tests to be "completed". The actual mechanics of datasonde data management is discussed in the Data Management section of this manual.

Data Quality Criteria

Data Quality is determined by comparison of datasonde results with audit sample results. It is important to recognize the environmental variables that will influence the quality of quality control audit samples. Examples of these variables are the natural diurnal oscillations of temperature, pH, dissolved oxygen and sometimes conductivity. When a water body has wide variations in these parameters, it is especially critical to minimize the error associated with sampling. Please see the final section of MOMs, Continuous Data Quality Assurance and Quality Control, for further information.

Glossary

ACCURACY - is the difference between the system reading and the "true" value. It can be specified as a percentage of the reading, a percentage of the full-scale reading, or as a plus-or-minus fraction. Uncertainty and error are often used synonymously to describe variations from the true value. Note that accuracy is strongly influenced by several operator-controlled variables, such as the quality of calibration standards, station residence time, sensor maintenance, and calibration technique and frequency.

DRIFT - is the long-term lack of repeatability caused by influences such as fouling of a sensor, shifts in calibration of a system, or slowly failing sensors. A post-calibration is perhaps the best indicator of drift under field conditions.

LINEARITY - is the relationship between the instrument's reading and a parameter's true value, as the parameter, but no other variable changes. Small, non-constant deviations from a slowly changing true value imply nonlinearity, whereas constant, predictable deviations from true value more likely represent a situation that the operator can correct by slope and/or zero adjustment, if available. The term "tracking" is often used interchangeably with linearity.

PRECISION - is a measure of an instrument's ability to reliably produce the same, unchanging reading under identical measurement conditions. Precision is not an indication of accuracy, since all those readings, though unvarying, might be completely wrong. The terms "repeatability" and precision are ordinarily used interchangeably.

RESOLUTION - specifies the smallest unit division that a system can display. Generally, resolution is much higher than overall accuracy, so that the last digit displayed is valuable only for setting exact calibration points or spotting trends as the value of the parameter being measured changes.

RESPONSE TIME - is the time required for a system to react, by a prescribed amount, to a step change in some variable.

TOLERANCE - has been used to mean several different things. It can refer to the maximum difference between the true value of a parameter and the actual reading that is acceptable to an operator; that is, the maximum error that an operator will tolerate. Notice that, in this sense, a system's accuracy must be better than or equal to the desired tolerance. Sometimes tolerance is used synonymously with accuracy.

ZERO and SLOPE - A system's "zero" is an anchor point set either temporarily by calibration or permanently by design. Slope is the operation applied to the system's response once the zero has been set. The two together define the calibration curve for a system. These two terms do not often appear on specification sheets, but are very important influences on accuracy. They can sometimes be set electronically (in which case stability becomes a question), but often are changed with each new calibration.

References

Hydrolab Corporation, 1993. . Hydrolab Corporation, Austin, TX *DataSonde 3 Multiparameter Water Quality Datalogger Operating Manual*.

YSI Incorporated. YSI 6920 *Multi-Parameter Water Quality Monitor Instruction Manual and Service Manual*. Yellow Springs, OH

US Dept of the Interior, US Geological Survey, 2006. *Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting. Techniques and methods 1-D3.* By Richard J. Wagner, Robert W. Boulger, Jr., Carolyn J. Oblinger, and Brett A. Smith.

APPENDIX A CALIBRATION OF YSI DATASONDES

CONTAINERS NEEDED TO CALIBRATE A DATASONDE

The calibration cup that comes with your datasonde serves as a calibration chamber for all calibrations and minimizes the volume of calibration reagents required. However, if you are using the 6026 "wiping" turbidity probe or the 6025 "wiping" chlorophyll probe, you should visually verify proper movement of the wiper mechanism before beginning the calibration procedures.

Instead of the calibration cup, you may use laboratory glassware to perform calibrations, if you do not use a calibration cup that is designed for the datasonde; you are cautioned to do the following:

- Perform all calibrations with the Probe Guard installed. This protects the probes from possible physical damage.
- Use a ring stand and clamp to secure the datasonde body to prevent the datasonde from falling over. Much laboratory glassware has convex bottoms.
- Insure that all sensors are immersed in calibration solutions. Many of the calibrations factor in readings from other probes (e.g., temperature probe). The top vent hole of the conductivity sensor must also be immersed during calibrations.

CHEMICAL SAFETY

To minimize the hazards of chemical exposure, handle all chemicals using safety goggles (with elastic band) and PVC gloves. To minimize chemical spills, handle the chemicals with caution and ensure container lids are tightly fastened. Be cognizant of laboratory safety manual, chemical hygiene plan,

CALIBRATION TIPS

1. If you use the Calibration Cup for dissolved oxygen (DO) calibration, make certain to loosen the seal to allow pressure equilibration before calibration. The DO calibration is a water-saturated air calibration.
2. The key to successful calibration is to insure that the sensors are completely submersed when calibration values are entered. Use recommended volumes when performing calibrations (see unit users manual).
3. For maximum accuracy, use a small amount of previously used calibration solution to pre-rinse the datasonde. You may wish to save old calibration standards for this purpose.
4. When calibrating for any parameters, standards and the datasonde probes should be as close to room temperature as possible, with minimal temperature difference between the probes and the standards, to minimize equilibration time.

5. Fill a bucket with room temperature water to rinse the datasonde between calibration solutions.
6. Have several clean, absorbent paper towels or cotton cloths available to dry the datasonde between rinses and calibration solutions. Gently, shake the excess rinse water off the datasonde, especially when the probe guard is attached.

CALIBRATION PROCEDURES

The following calibration procedures are for the most commonly used sensors.

To ensure more accurate results, rinse the calibration cup with distilled water and then rinse with a small amount of the calibration solution for the sensor you are going to calibrate. Discard the rinse solution and add fresh calibration solution.

1. Carefully immerse the probes into the solution and rotate the calibration cup to engage several threads. Support the datasonde with a ring stand and clamp to prevent the datasonde from falling over.
2. With a field cable connecting the datasonde to a PC, access *EcoWatch for Windows* and proceed to the Main menu (for information on how to run *EcoWatch for Windows* software). From the datasonde Main menu, select number **2-Calibrate**.

TEMPERATURE

The datasondes use a thermistor of sintered metallic oxide that changes predictably in resistance with temperature variation. The algorithm for conversion of resistance to temperature is built into the datasonde software, and accurate temperature readings in degrees Celsius, Kelvin, or Fahrenheit are provided automatically. No calibration or maintenance of the temperature sensor is required.

Expired reagents affect analytical results!

Ensure that reagents, buffers, and standards are not beyond their expiration date (as indicated on the container) or otherwise appear contaminated.

Conductivity standards: Expiration date is six months from the fill date.

pH buffers: When using pH buffers directly from the primary container, observe the manufacturer's expiration date. Expiration date for secondary containers is one year from the fill date.

Sodium thiosulfate: Expiration date is six months from the fill date.

All other DO reagents: Expiration date is one year from the fill date.

Spent concentrated acids and bases should be neutralized or diluted and flushed down the deep sink with excess water: ***turn on a faucet in a laboratory sink and then slowly pour the chemical into the stream of water to be flushed down the drain.***

CONDUCTIVITY

This procedure calibrates conductivity, specific conductance, salinity, and total dissolved solids.

1. Place approximately the correct amount of conductivity standard into a clean, dry or pre-rinsed calibration cup. For maximum accuracy, the conductivity standard you choose should be within the same conductivity range as the water you are preparing to sample. However, YSI does not recommend using standards less than 1 mmhos/cm (1000 µmhos/cm). For example:
   - For fresh water use a 1 mmhos/cm (1000 µmhos/cm) conductivity standard.
   - For brackish water use a 10 mmhos/cm (10,000 µmhos/cm) conductivity standard.
   - For seawater use a 50 mmhos/cm (50,000 µmhos/cm) conductivity standard.
2. Before proceeding insure the sensor is as dry as possible. Ideally, rinse the conductivity sensor with a small amount of standard that can be discarded. Be certain that you avoid cross-contamination of standard solutions with other solutions. Make certain that there are no salt deposits around the oxygen and pH/ORP probes, particularly if you are employing standards of low conductivity.
3. Carefully immerse the probe end of the datasonde into the solution. Gently rotate and/or move the datasonde up and down to remove any bubbles from the conductivity cell. The probe must be completely immersed past its vent hole. Using the recommended volumes from the table in the previous subsection should insure that the vent hole is covered.
4. Allow one minute for temperature equilibration before proceeding. At the end of the one minute temperature equilibration period, calibrate the conductivity probe as specified by the manufacturer. (Note: When conductivity probes are submersed in conductivity standard, it is imperative that the datasonde probes not be left submersed in conductivity standard solution for longer than the calibration period (approximately 1-2 minutes, maximum). Reference electrode solution from the pH probe can sequentially increase the conductivity of your standard, thereby falsely increasing your conductivity measurement and calibration.)
5. From the Calibrate menu, select number **1-Conductivity** to access the Conductivity calibration procedure and then number **l-SpCond** to access the specific conductance calibration procedure. Enter the calibration value of the standard you are using (**mmhos/cm at 25°C**) and press **Enter**. The current values of all enabled sensors will appear on the screen and will change with time as they stabilize.
6. Observe the readings under Specific Conductance or Conductivity and when they show no significant change for approximately 30 seconds, press **Enter**. The screen will indicate that the calibration has been accepted and prompt you to press **Enter** again to return to the Calibrate menu.
7. Rinse the datasonde in tap or distilled or purified water and dry the datasonde.

PH 2-POINT

Using the correct amount of pH 7 buffer standard in a clean, dry or pre-rinsed calibration cup, carefully immerse the probe end of the datasonde into the solution. Allow at least 1 minute for temperature equilibration before proceeding.

From the Calibrate menu, select number **4 pH** to access the pH calibration choices and then press number 2- 2-Point. Press **Enter** and input the value of the buffer (7 in this case) at the prompt. Press **Enter** and the current values of all enabled sensors will appear on the screen and change with time as they stabilize in the solution. Observe the readings under pH and when they show no significant change for approximately 30 seconds, press **Enter**. The display will indicate that the calibration is accepted.

After the pH 7 calibration is complete, press **Enter** again, as instructed on the screen, to continue. Rinse the datasonde in water and dry the datasonde before proceeding to the next step.

Using the correct amount of an additional pH buffer standard (pH **4 or pH 10**) into a clean, dry or pre-rinsed calibration cup, carefully immerse the probe end of the datasonde into the solution. Allow at least 1 minute for temperature equilibration before proceeding.

Press **Enter** and input the value of the second buffer at the prompt. Press **Enter** and the current values of all enabled sensors will appear on the screen and will change with time as they stabilize in the solution. Observe the readings under pH and when they show no significant change for approximately 30 seconds, press **Enter**. After the second calibration point is complete, press **Enter** again, as instructed on the screen, to return to the Calibrate menu.

Rinse the datasonde in water and dry. Thoroughly rinse and dry the calibration containers for future use.

DISSOLVED OXYGEN

Principles of Operation

Datasondes employ the patented YSI Rapid Pulse system for the measurement of dissolved oxygen (DO). Use of this technology provides major advantages for the monitoring of DO without significantly compromising the accuracy of sampling applications. Standard electrochemical detectors of DO are highly flow-dependent and therefore require external stirring of the medium being evaluated. This stirring must be supplied either by an auxiliary stirrer (which can consume much of the battery reserve in a portable system) or by manually agitating the datasonde when carrying out spot sampling applications (which can be inconvenient). These disadvantages are overcome by the Rapid Pulse dissolved oxygen technology that is associated with the datasonde because it needs no stirring to yield accurate readings. In addition, because of the nature of the technology, some effects of fouling of the sensor are minimized.

The Rapid Pulse system uses a Clark-type sensor that is similar to other membrane-covered steady-state dissolved oxygen probes. The system still measures the current associated with the reduction of oxygen which diffuses through a Teflon membrane, and this current is still proportional to the partial pressure (not the concentration) of oxygen in the solution being evaluated. The membrane isolates the electrodes necessary for this reduction from the external media, encloses the thin layer of electrolyte required for current flow, and prevents other non-gaseous, electrochemically active species from interfering with the measurement. However, as the user will note from examination of the 6562 probe, the sensor consists of three electrodes (a cathode, anode, and reference electrode) while steady state Clark probes usually have only two electrodes (a cathode and a combined anode-reference electrode). In addition, the geometry of the sensor is novel, consisting of a thin linear gold cathode placed between two silver rectangles which serve as anode and reference electrodes. These sensor changes were required to implement the new Rapid Pulse method for DO measurement as described in the following section.

Standard Clark dissolved oxygen sensors, which are marketed by YSI and other manufacturers, are continuously polarized at a voltage sufficiently negative to cause oxygen to be reduced to hydroxide ion at the cathode and silver metal to be oxidized to silver chloride at the anode. The oxygen diffuses through the Teflon membrane. The current associated with this process is proportional to the oxygen present in the solution outside the membrane. However, as this electrochemical reaction proceeds, oxygen is consumed (or depleted) in the medium, resulting in a decrease in measured current (and apparent oxygen content) if the external solution is not stirred rapidly. To minimize this oxygen depletion, the probe electrodes in the YSI Rapid Pulse system are rapidly and reproducibly polarized (on) and depolarized (off) during a measurement sequence. The Rapid Pulse system thus measures the charge or coulombs (current summed over a specific time period) associated with the reduction of oxygen during a carefully controlled time interval. The coulombs due to charging of the cathode (capacitance), but not to reduction of oxygen, are subtracted during integration after the cathode has been turned off. The net charge, like the steady state current in a standard system, is proportional to the oxygen partial pressure in the medium. Because oxygen is only being reduced 1/100th of the total measurement time, even if the probe is pulsed in this manner continuously, oxygen consumption outside the membrane is kept to a minimum, and the stirring dependence of the system is greatly reduced.

One key to the practicality of the Rapid Pulse oxygen system is that the "on time" is very short. This allows the "off time" to also be relatively short and still maintain the off-to-on ratio of 100 which is necessary to obtain relatively flow-independent measurements. The second important aspect of the Rapid Pulse technology is the integration (summing of the current) over the total pulse (on and off). Because the charging current of the electrodes is subtracted in this process, the net signal is due only to the reduction of oxygen. From a practical point of view, this means when there is zero oxygen partial pressure outside the membrane, the Rapid Pulse signal will also be zero; this in turn allows the system to be calibrated with a single medium (air or water) of known oxygen pressure.

Calibration and Effects of Temperature and Pressure

The DO readings of steady state oxygen systems are greatly affected by temperature due to the effect of temperature on the diffusion of oxygen through the membrane (approximately 3% per degree Celsius). The Rapid Pulse system exhibits a greatly reduced effect of temperature (approximately 1% per degree Celsius), but this factor still must be accounted for if DO readings acquired at temperatures different from that at calibration are to be accurate. The datasonde software automatically carries out this compensation.

In addition, the relationship between the measured partial pressure of oxygen (percent saturation) and the solubility of oxygen in mg/L is very temperature dependent. For example, air saturated water (100 percent saturated) at 20° C contains 9.09 mg/L, but only 7.65 mg/L at 30° C. The datasonde software compensates for both of these temperature-related factors after instrument calibration. The temperature compensation for the percent saturation reading is empirically derived, while the conversion from percent saturation and temperature to solubility in mg/L is carried out using formulae available in Standard Methods for the Examination of Water and Wastewater (ed. 1989, see Appendix D, Solubility and Pressure/Altitude Tables for dissolved oxygen solubility tables as a function of salinity and temperature).

The datasonde Rapid Pulse system is calibrated using the same basic methods employed for steady state oxygen sensors. However, the software that controls the calibration protocol is somewhat different depending on whether the unit will be used in sampling or deployment studies. For sampling studies using either a 610 display unit or a laptop computer, the Rapid Pulse system is allowed to run

continuously when the Run mode is activated if "Autosleep" is turned off. Under these software conditions, the user views the DO readings in real time and confirms the calibration manually after the readings have stabilized.

For studies in which the datasonde is deployed and readings are saved less frequently (5 — 60 minutes) to datasonde memory on a computer or data collection platform, an appropriate warm up time is selected for the system during Sensor setup. Usually 40 seconds is adequate for this parameter, but in some cases larger values may result in more accurate results. Most importantly for deployment studies, "Autosleep" should be activated. With these software entries in place, the user will input the calibration value (concentration or barometric pressure), and the unit will automatically calibrate after the selected warm up time.

NOTE: Remember that control of the calibration will be manual rather than automatic if the unit is set up properly for spot sampling applications ("Autosleep" deactivated). The description below is designed around deployment applications with "Autosleep" activated.

The two general calibration methods possible with the datasonde are "DO mg/L" and "DO %". The former method is designed for calibration *in situ* while the latter uses water-saturated air as the medium. Since the percent saturation (DO %) and concentration (DO mg/L) values are related, calibration by either method results in correct outputs in both units.

DO mg/L Calibration Method

1. If the DO mg/L method is selected from the datasonde Calibrate menu, the DO concentration of an aqueous solution must first be determined by either of the following methods:
    - Winkler titration
    - Aerating the solution and assuming that it is saturated, or
    - Measurement with another instrument.
2. Place the datasonde into this known-value solution and wait 5-10 minutes for equilibration to occur to thermally equilibrate the datasonde casing. All algorithms are temperature based.
3. Then input the value (in mg/L) into the datasonde software and begin the calibration protocol according to the instructions. The calibration will occur automatically at the end of the specified warm-up time.
4. Confirm that reading is stable by performing replicate measurements via one of the three methods described in step 1.

DO % Calibration Method

1. If the Percent Saturation method is selected, the datasonde is simply placed in a calibration cup that contains a small quantity of water or a damp sponge. The probe sensor should not be in the water for this calibration procedure.
2. The datasonde should be left under these conditions for 10-15 minutes to allow temperature and humidity equilibration to occur.

3. Then input the true barometric pressure into the datasonde software and begin the calibration protocol according to the instructions. The calibration will occur automatically at the end of the specified warm-up time.

True barometric pressure is the barometric pressure uncorrected for sea level. Most meteorological stations and airports correct barometric pressure to sea level. Correct field DO Saturation calibrations use raw barometric pressure. Barometric measurements are made with a YSI 650 handheld data acquisition unit with a digital barometer. The digital barometer is checked against the NIST-traceable mercury barometer housed in the ODEQ Air Monitoring Department. If calibration is needed (as indicated when reading on digital barometer compared to the NIST-traceable barometer is > ± 5 mm Hg), the adjustment and recalibration is noted on the reverse side of the YSI 650.

Flow Dependence

As noted above, oxygen readings acquired using the Rapid Pulse technology are much less affected by sample flow than steady state probes. However, there is a finite stirring dependence exhibited by the Rapid Pulse system if measurements are taken when the probe is being pulsed continuously. YSI tests indicate that, under these sampling conditions, observed dissolved oxygen readings can be 2-3 percent lower than the true readings in very still water. Minimal movement of the water (which occurs during most environmental measurements) removes this effect.

This small flow dependence of the sensor is greatly reduced in longer term monitoring deployments where the sampling interval is longer, e.g. 15 minutes. Under these conditions, the sensor is pulsed for only approximately 40 seconds every 15 minutes, and normal diffusion of oxygen in the medium re-establishes the oxygen which has been depleted in the previous warm-up/read sequence.

Measurement and Calibration Precautions

Make sure to check the cathode/anodes on the DO probe for corrosion/tarnishing. Replacement of the DO membrane and KCl solution should be completed on a regular maintenance schedule.

1. Place approximately 3 mm (1/8 inch) of water in the bottom of the calibration cup. Place the probe end of the datasonde into the cup. Make certain that the DO and temperature probes are immersed in the water. Engage only 1 or 2 threads of the calibration cup to insure the DO probe does not touch the bottom of the cup.
2. If water-saturated air is used as the calibrating medium, make certain that both the DO reading and the temperature have stabilized (10-15 minutes) before starting the calibration sequence. A wet thermistor can indicate artificially low temperature readings due to evaporation and this situation will result in poor temperature compensation and inaccurate readings.
3. Insure that the calibration cup being used is vented or pressure released.

4. For short term storage (2 weeks or less), keep the probe moist when not in use, either by immersing in water or by placing a damp sponge in the calibration vessel. For longer-term storage, remove the probe from the datasonde and store it in water with a membrane and electrolyte in place. If the membrane appears to be damaged or has dried out, be sure to replace it prior to calibration and deployment.
5. For maximum accuracy calibrate the Rapid Pulse system at a temperature as close as possible to that of the sample being measured. One method of accomplishing this involves immersing the calibration chamber (which contains either a small amount of water or a wet sponge) into the body of water that is later to be measured. Do not allow the sample water to seep into the calibration chamber. Monitor the readings. After thermal equilibrium has been established, proceed with the calibration. Note that under normal circumstances this procedure is not required.
6. Before you install a new membrane, make sure that the O-ring groove and the probe tip are clean and smooth. If the KCl electrolyte solution leaks from the probe surface during monitoring studies, the readings are likely to be less accurate in a shorter period of time.

DEPTH AND LEVEL

Principles of Operation

The voltage output of the transducer is directly proportional to the pressure. The datasonde software converts this voltage to a depth reading in feet or meters via calibration parameters that are factory installed. Readings are automatically compensated for the temperature and for the density of the environmental medium, which is estimated from the measured salinity.

For the depth and level calibration, you can leave the datasonde set up the same way as for dissolved oxygen, in water-saturated air.

From the Calibrate menu, select number **3-Pressure-Abs** (or number 3-Pressure-Gage if you have a vented level sensor) to access the depth calibration procedure. Input 0.00 or some known sensor offset in feet. Press **Enter** and monitor the stabilization of the depth readings with time. When no significant change occurs for approximately 30 seconds, press **Enter** to confirm the calibration. This zeros the sensor with regard to current barometric pressure. Then press Enter again to return to the Calibrate menu.

For best performance of depth measurements, users should ensure that the datasonde's orientation remains constant while taking readings. This is especially important for vented level measurements and for datasondes with side mounted pressure sensors.

Calibration and Effect of Temperature

The depth sensor must be zeroed prior to deployment to account for atmospheric pressure. Level sensors may also require a small adjustment prior to their first use. This procedure is carried out by following the calibration menu instructions with the datasonde in air only (do not submerge). The sensors can also be set to any known depth via the calibration routine after they are immersed. The temperature dependence of the sensor is automatically taken into account by the datasonde software based on input from factory calibration.

Measurement and Calibration Precautions

1. Be certain that the datasonde is not immersed in water during the calibration procedure unless you know the exact distance between the sensor and the water surface. Calibration (zeroing) in air is usually the recommended method.
2. Remember that the dcp sensors for the datasonde are not vented. In practical terms, this means that changes in barometric pressure after the sensor is calibrated will appear as changes in depth. This effect is significant, particularly for the 0-30 ft option of the depth probe. For example, a change of 1 mm of Hg in barometric pressure will change the apparent depth by approximately 0.045 feet (0.012 m). As noted above, this error is eliminated for level sensors because they are vented to the atmosphere.

APPENDIX B CALIBRATION OF HYDROLAB DS-3

The multi-probe is calibrated by pouring a calibration standard into the calibration cup (or immersing the entire multi-probe in a bucket of standard) and watching the readings (for the parameter to be calibrated) in the Standard Operating Mode (SOM). When the readings stabilize (meaning that step- response and/or temperature transients have disappeared), the Basic Menu is accessed by hitting the terminal's space bar. Typing a **C** will then produce the Calibrate menu, from which the particular parameter value can be set.

The DS3 Multi-probe has built-in checks for calibration acceptance. If a sensor's response is significantly different from the calibration value you type in, the calibration value will not be accepted. For example, if you type in 7.02 for a pH calibration, but have accidentally immersed the sensors in a buffer of value 9.18, the message "**NC**" will appear, the terminal's bell will ring once, and you will be returned to the SOM. If for any reason you cannot complete calibration for any parameter, the multi-probe will continue to use the calibration from the last time that particular parameter was calibrated. However, you should try to determine why the multi-probe will not accept the new calibration (faulty sensor, bad standard, low battery, miss-typed standard value, etc.).

If any parameter values are accompanied by an asterisk (*), then that value is based on a default calibration setting. This means the multi-probe has, for some reason, forgotten the calibration information provided for that particular sensor, and has replaced (i.e., defaulted) it with a nominal calibration setting. So, the sensor must be recalibrated. Note that some calibrations affect other parameters. For example, loss of calibration information for specific conductance will cause an asterisk annotation for specific conductance, salinity, dissolved oxygen (ppm), and depth readings, since each is calculated from, or influenced by, the specific conductance reading.

MAINTENANCE

Care of the Multi-probe

Besides normal maintenance of the sensors and the internal batteries, just clean the multi-probe with soap and water. Always use the calibration cup or the storage cup (filled with tap water) to protect the sensors from damage, and especially from drying out, whenever the multi-probe is not deployed.

Remember when using the polarizing batteries, you can greatly prolong the life of the sensor by changing the electrolyte frequently (twice or more a month), and/or by removing the electrolyte when the sensor is not to be used for a week or more.

Always rinse the multi-probe with clean water soon after returning from deployment.

Care of the Cables

Keep these parts clean and off the floor. Additionally, some connectors, such as any that plug into a terminal, are not waterproof and so must be kept dry at all times.

Protect the cables from abrasion, unnecessary tension, repetitive flexure (fatigue), and bending over sharp radii (like the edge of the side of a boat). Excessive weight added to the transmitter (10 pounds or more) can greatly increase the possibility of cable breakage due to stress on the mold and attachment points.

When not in use, cables should be clean, dry, and stored, neatly coiled, in a plastic bag.

If your DS3 Multi-probe is equipped to measure dissolved oxygen (DO), Redox, or pH, you need to decide whether or not to use the DS3's internal polarizing batteries. These are two Mallory TR-132R (or equivalent) 2.7 volt mercury batteries. When installed inside the multi-probe, they eliminate the need to wait over two minutes for stable readings once the multi-probe has been turned on.

The polarizing batteries are shipped in the maintenance kit. Install them if you wish to eliminate the two-minute "warm-up" time for pH or the Standard Membrane DO sensor. Warm-up times are approximate and can change with such variables as temperature.

Here's an example of when to use, or not use, the polarizing batteries:

> Joe had three multi-probes that he was using to monitor fish-rearing tanks. The multi-probes were equipped with Standard Membrane DO sensors and pH sensors, and Joe needed measurements from all three tanks every 15 minutes. Joe elected to use the multi-probes without polarizing batteries, since he could program his computer to turn each multi-probe on for five minutes - more than enough time to produce stable readings for pH and Standard Membrane DO.
>
> However, things worked out so well that six months later Joe added 27 more tanks. Now, he can turn each multi-probe on for at most 30 seconds - not enough time to guarantee stable readings without the polarizing batteries. So, Joe installed the polarizing batteries in all his multi-probes and adopted a new maintenance plan that required weekly electrolyte and membrane changes for the DO sensors.
>
> Had Joe been using the Lo-Flow Membranes, he would always have had to use the polarizing batteries, since even two minutes is not a long-enough warm-up for the Lo-Flow Membrane.

To change or install the batteries, first put the dummy cap back onto the 6-pin bulkhead connector (if you have a detachable cable). Don't leave the sensors unguarded; always attach either the storage cup or calibration cup to the multi-probe. Take the multi-probe over to the sink and scrub it all over with a vegetable brush and soapy water.

When it is cleaned and dried, remove the two Allen screws that hold the multi-probe's bottom cap (the cap with the sensors) fixed in the multi-probe's tubular body. Now carefully and slowly (with a slight twisting motion) remove the bottom cap, using, if necessary, a large screwdriver blade between the cap and multi-probe body (just to get it started). Pull the cap out only about six inches (it is very tight and might come free suddenly; don't fling it across the room). Lift the cap straight out of the housing, slowly, until you can see the wires connecting the multi-probe's external connector (the one at the top of the multi-probe) to the rectangular circuit boards. Carefully detach the wires' connector from the exposed circuit boards so that you can finish pulling the circuitry out of the tube. Set the tube aside, making sure that no contaminants enter the opened end.

Now, remove the spent batteries from their holders and replace them with fresh batteries; observe the polarity markings of the battery holders.

Re-install the retaining clips.

Examine the O-rings on the cap and the area inside the tube which seats the o-rings.

- Is there any sign of nicks, gouges, or flattening of the o rings?
- Is the seating area undamaged?

- Is everything incredibly clean; no sand, hair, grit, dirt, sediment, sticks, etc.?
- Is there a light coat of white silicone grease (supplied in the maintenance kit) present?
- *This is the moment of truth. If you are in a big hurry at this point, check the price of a new multi-probe before proceeding.*

When you are satisfied that the O-rings and seats are ready for re-assembly, slide the circuitry back in the tube, remembering to reconnect the wires to the circuit board as they were connected before. Now push the bottom cap back into the tube (with a slight twisting motion). Add a small amount of anti-seizing compound or light grease to the Allen screw threads to prevent seizing of screws and replace the screws with a small Allen wrench (just finger-fight).

DO NOT OVER-TIGHTEN!

These batteries power the dissolved oxygen sensor (and pH and Redox amplifiers) continuously, so that a stable reading is always available. When these batteries are changed, be prepared to wait a few hours or overnight for the DO sensor to restabilize. If you know that the multi-probe is not going to be in use for an extended period, say a week or more, you can extend the life of the two batteries and of the oxygen sensor by removing the membrane and the entire electrolyte, and installing a new membrane over the dry sensor. For best results, replace the electrolyte and membrane on the day before calibrating for the next deployment.

CALIBRATION

Temperature

Because of the unvarying nature of the temperature sensor and its conditioning circuitry, the temperature calibration is factory-set and requires no recalibration. The sensor is built into the specific conductance probe, and requires no maintenance.

Specific Conductance and Salinity

Specific Conductance ranges are divided to maximize measurement resolution. The fresh water cell block provides the ranges 0 to 0.15, 0.15 to 1.5, and 1.5 to 10 mmhos/cm. The salt water cell block provides the ranges 0 to 1.5, 1.5 to 15, and 15 to 100 mmhos/cm. The salt water cell block should be used only if specific conductances greater than 10 mmhos/cm are anticipated.

To maintain the sensor, remove the white cell block covering the six pin-shaped nickel electrodes of the specific conductance sensor. Remove the six small O-rings that are slipped over the electrodes and polish the entire exposed surface of the electrodes with the emery cloth supplied in the multi-probe's maintenance kit, or with #400 wet/dry sandpaper. Be sure to polish the ends of the electrodes, but be careful not to touch the nearby pH glass electrode with the abrasive. Clean the electrodes and the cell block with an alcohol-soaked swab.

Expired reagents affect analytical results!

Ensure that reagents, buffers, and standards are not beyond their expiration date (as indicated on the container) or otherwise appear contaminated.

Conductivity standards: Expiration date is six months from the fill date.

pH buffers: When using pH buffers directly from the primary container, observe the manufacturer's expiration date. Expiration date for secondary containers is one year from the fill date.

Sodium thiosulfate: Expiration date is six months from the fill date.

All other DO reagents: Expiration date is one year from the fill date.

Spent concentrated acids and bases should be neutralized or diluted and flushed down the deep sink with excess water: ***turn on a faucet in a laboratory sink and then slowly pour the chemical into the stream of water to be flushed down the drain.***

Re-install the six O-rings (replace the O-rings if they have been flattened-out by long service). Re-install the white cell block; tightening the screws just enough to make sure the cell block is seated flat against the specific conductance sensor body. Once the sensor has been rinsed well with deionized water, it can be calibrated. It is good practice, however, to let the sensor soak in tap water overnight to allow freshly-polished electrode surfaces to re-equilibrate with an aqueous environment.

When calibrating specific conductance, use a standard whose specific conductance is near that of your field samples; for instance, don't use 1M KCl to calibrate for fresh water work. Unless you are practiced in quantitative preparations, or know someone who is, you are better off purchasing prepared specific conductance standards.

For calibration, first make sure that the multi-probe knows which cell block is employed. Next, make sure the sensor is clean and serviced. Then:

1. Thoroughly rinse the sensors several times by half-filling the calibration cup with deionized water and shaking the multi-probe to make sure each sensor is free from contaminants that might alter your specific conductance standard.
2. In a similar manner, rinse the sensors twice with a small portion of the specific conductance standard to be used for calibration, each time discarding the rinse.
3. With the calibration cup screwed onto the multi-probe, sensors pointed toward the ceiling, pour in the standard to within a centimeter of the top of the cup, making sure there are no bubbles in the bores of the cell block.
4. Watch the specific conductance readings until they have stabilized; the sensor is now ready for calibration.
5. Access specific conductance from the calibrate menu, type in the calibration standard value, and hit the return key to revert to the SOM.

* If turbidity is installed, the pH and redox sensors are combined into a single 'combo' sensor.

Note: The Depth sensor is mounted inside the Multi-probe. A seal screw can be used to protect the sensor from over- range damage.

Because the salinity parameter is algorithm-generated from the specific conductance reading, once you have calibrated specific conductance, you have also calibrated salinity. However, if your field work requires salinity rather than specific conductance readings, you should calibrate salinity instead of specific conductance. Simply access salinity instead of specific conductance from the calibrate menu and type in the value (in parts per thousand at 25°C) of your salinity standard. Note that calibrating salinity simultaneously calibrates specific conductance. You cannot separately calibrate both salinity and specific conductance.

pH

The pH glass electrode requires maintenance only when obviously coated with oil, sediment, or biological growth. Clean the glass with a very clean, soft, non-scratching cloth wetted with rubbing alcohol (a cotton ball will do).

Slow response or non-reproducible measurements are signs that the electrodes have become coated or clogged.

The pH glass electrode is susceptible to coating by many substances. The speed of response, normally 95% of the reading in less than 90 seconds, is dramatically changed. Usually a rinse with methyl alcohol will remove any films on the glass and restore the speed of response.

If the methanol rinse does not restore the response, soak the electrode in 0.1 M HCl for five minutes. Remove and rinse the electrode with water and rinse the electrode in pH buffer for 10 minutes. This should improve the response.

Servicing the reference electrode mainly involves replacing the electrolyte by gently pulling the entire covering sleeve away from the multi-probe body. Empty the remaining electrolyte from the reference sleeve and refill the sleeve to the top with standard electrolyte: three- or four-molar KCl saturated with silver chloride.

With the multi-probe sensors pointed toward the floor, push the full reference sleeve back onto its mount until the sleeve has just covered the O-ring located on the mount (just behind the silver electrode). Now turn the multi-probe so that the sensors point toward the ceiling and push the sleeve the rest of the way onto its mount. Notice that while you are seating the sleeve, you are purging any air trapped in the electrolyte chamber, and are using the air and excess electrolyte to flush and clean the porous junction on the tip of the sleeve. This junction is the most important part of the pH system; make sure it is clean and passes electrolyte readily. If not, replace it with the spare in the maintenance kit.

The pH system can now be calibrated. However, it is a good idea to let the electrodes re-equilibrate overnight in tap water after being cleaned, especially if you have used alcohol.

pH calibration is accomplished by filling the calibration cup first with the “zero” buffer (value between 6.8 and 7.2) and then with a “slope” buffer whose pH is near that of the anticipated samples to be measured (but not between 6.8 and 7.2). Always rinse the sensors thoroughly with deionized water between buffers.

The general-purpose Hydrolab reference electrode is designed for normal field application: measurement of middle-range ionic strength waters to about 150 meters depth. For use in very low ionic-strength waters (generally, those under 0.2 mmhos/cm specific conductance), measurement reliability can often be enhanced by the LISREF (an optional one-piece, white, bullet- shaped "low ionic-strength reference electrode" that does not require electrolyte replacement). The LISREF requires a maintenance procedure different from that prescribed for the rebuildable Hydrolab reference.

First, and most importantly, the tip of the LISREF should be soaked in 4M potassium chloride whenever the system is not in use; for instance, overnight when the instrument is in daily use. Fill with KCl the black cap provided with the LISREF (or a similar cap) and install it on the LISREF for this storage procedure, since the other sensors, such as the pH glass itself, should be stored in plain tap water. This step facilitates a reference junction that is homogeneously saturated with strong electrolyte, a condition necessary for stable and accurate readings in dilute samples. Be sure to remove the black cap for calibration or field use.

As a rule of thumb, make sure the LISREF reference electrode is soaked in KCl as long, per week, as it is exposed to sample waters.

Second, always keep the LISREF clean by rinsing with soapy water to remove visible contamination, and by wiping the sensor occasionally with a cloth soaked in rubbing alcohol to remove oils and grease that might have accumulated. The sensor should be soaked in KCl at least 24 hours after cleaning, and then recalibrated before field use.

Third, check the sensor's span frequently by calibrating with standard buffers and then checking performance with a standard whose ionic strength approximates that of the anticipated field samples. Calibration with standard buffers alone is no guarantee of measurement quality in low ionic-strength samples.

Slow response or non-reproducible measurements are signs that the electrodes have become coated or clogged. The pH glass electrode is susceptible to coating by many substances. The speed of response, normally 95% of the reading in less than 90 seconds, is dramatically changed. Usually a rinse with methyl alcohol will remove any films on the glass and restore the speed of response.

If the methanol rinse does not restore the response, soak the electrode in 0.1 M HCl for five minutes. Remove and rinse the electrode with water and rinse the electrode in pH buffer for 10 minutes. This should improve the response.

Dissolved Oxygen

DO sensor maintenance is usually required only when calibration becomes impossible or when the membrane covering the cell becomes wrinkled, bubbled, torn, dirty, or otherwise damaged. It is, however, good practice to replace the membrane on a regular schedule, before trouble becomes visible. Frequent electrolyte changes will maximize the life of the sensor.

To change membranes, remove the white DO sensor guard and the O-ring securing the membrane. Gently, shake out the old electrolyte, rinse with deionized water, and refill with fresh electrolyte (provided in the Maintenance Kit, or use 2M potassium chloride) until there is a perceptible meniscus of electrolyte rising above the entire electrode surface of the sensor. Make sure that there are no bubbles in the electrolyte. Hold one end of a new membrane (either Standard or Lo-Flow) against the body of the

DO sensor with your thumb and with a smooth, firm motion, stretch the other end of the membrane over the sensor surface and hold it in place with your index finger. Secure the membrane with the O-ring.

Note: When applying a Lo-Flow membrane, be sure to stretch the membrane just enough to have it conform to the sensor without wrinkles. If you stretch it too tight, the readings will be too high for calibration. If such is the case, simply replace the membrane, without quite so much stretch, and recalibrate. There should be no wrinkles in the membrane or bubbles in the electrolyte. Trim away the excess membrane extending below the 0-ring.

The DO sensor is now ready for calibration, but you should let it soak overnight to give the membrane time to relax to its final shape (i.e., calibration condition).

To calibrate DO:

1) With the multi-probe oriented so that the sensors are pointed toward the ceiling, fill the calibration cup with tap water (specific conductance less than 0.5 mmhos/cm) until the water is just level with the O-ring used to secure the membrane.

2) Carefully remove any water droplets from the membrane with the corner of a tissue.

3) Turn the calibration cup cover upside down (concave upward) and lay it over the top of the calibration cup.

4) The sensor is ready for calibration once the readings have stabilized. Just follow the instructions printed by the multi-probe; refer to sections for calibration menu details.

You can also calibrate the DO system in a well-stirred bucket of temperature-stable, air-saturated water. This situation more closely resembles the actual field measurement conditions.

Remember that the two batteries in the multi-probe can power the oxygen sensor (and the pH circuits) continuously, so that a stable reading is always available quickly. Generally, the polarizing batteries are used only with the Lo-Flow Membrane. If you know that the multi-probe is not going to be in use for an extended period, say a week or more, you can extend the life of the two cells and of the oxygen sensor by removing the sensor's membrane, removing the sensor's entire electrolyte, and installing a membrane over the dry sensor. For best results, replace the electrolyte and membrane the day before calibration for the next deployment. When using the polarizing batteries, you can greatly prolong the life of the sensor by changing the electrolyte frequently (twice or more a month), and/or by removing the electrolyte when the sensor is not to be used for a week or more.

Depth

Generally, the depth (or level) sensor needs no maintenance. Occasionally, you may wish to squirt a very weak acid (such as acetic) into the depth sensor port (the hole in the face of the bottom cap that seems to have no use) with a hypodermic syringe if you notice deposits (calcium, biological growth, etc.) forming in the port.

Normally, calibration is done by simply entering zero for the standard at the water's surface. However, if you have another method, such as a carefully-marked cable, you can type in any number you wish when calibrating.

Because the density of water varies with its specific conductance, the depth readings must be corrected for specific conductance. This correction is applied linearly from zero specific conductances (no correction) to 100 mmhos/cm. At 52 mmhos/cm (seawater's specific conductance), the correction reduces the actual reading by 3 percent.

Note that there are two depth sensors: 0 to 100 meters (328 feet) and 0 to 10 meters (33 feet). The former is usually used to determine the depth at which readings of the other parameters are being made. The latter is often used to detect level changes, such as those accompanying tidal flows or rainfalls. The level sensor should be protected from depths over 20 meters (66 feet) by installing the sealing screw (found in the maintenance kit) in the face of the bottom cap. Likewise, the depth sensor should be protected from depths over 150 meters (492 feet) by installing the sealing screw.

APPENDIX B Calibration of Hydrolab DS-3

SEDIMENT OXYGEN DEMAND – In-situ Measurement

Scope and Application

A comparative study (Murphy and Hicks, EPA Region IV, 1986) of laboratory and field methods for measuring sediment oxygen demand (SOD) found that in-situ methods provide a better estimate of SOD rates, and yield relatively precise results. In-situ methods cause less sediment disturbance, and allow measurement under near ambient conditions. Minimizing sediment disturbance is critical since resuspension or compaction can seriously affect SOD rates.

In-situ SOD measurement involves isolating a known volume of water and area of sediment under an opaque chamber on the river or lake bed. The dissolved oxygen concentration in the chamber is monitored for a sufficient time to measure a rate of change in dissolved oxygen concentration. A sealed "blank" chamber similar to the measuring chamber provides an estimate of the water column respiration rate. The water column respiration is subtracted from the total oxygen demand, and the SOD is then calculated as $g/m^2 \cdot day$. In water too deep or cold for wet wading, the SOD chambers must be installed by qualified scuba divers.

Murphy and Hicks (EPA Region IV, 1986) developed a standardized method for in-situ SOD measurement. The Oregon DEQ Laboratory designed an SOD chamber similar to EPA's in terms of circular shape, removable lid, volume to surface area ratio, depth of cutting flange, and internal circulation rate. The chamber was constructed from a cross-section of a 55-gallon drum, and differs from the EPA design in that it lacks an internal central core. Despite this difference, the DEQ chamber generates a circular flow pattern without excessive resuspension. The DEQ chamber has several design advantages that include the use of a very simple circulation system with minimal plumbing. This makes it easy to purge the system and eliminate trapped air bubbles. The design uses an internally mounted multi-parameter datasonde that allows simultaneous recording of DO, pH, conductivity, temperature, and turbidity. The inclusion of these additional parameters can be quite valuable when evaluating the success of a SOD measurement. For example, conductivity readings can be used to assess whether the chamber maintained an adequate seal on the substrate, particularly in estuarine water or if a KCl spike is used. Since all instrumentation and components are mounted on the removable lid, the chamber volume to surface area ratio can be adjusted by using different size chamber bodies. This allows the chamber to be used over a range of SOD rates and water column DO concentrations. When selecting a chamber volume, one must consider that enough DO must be present in the chamber to sustain the measurement for about 2 hours (longer deployments risk the "bottle effect" and the growth of microbial slimes on the chamber walls). If the chamber volume is too low the DO in the chamber may be depleted before enough data are collected to calculate the SOD rate. If the chamber is too large relative to the SOD, the DO decay in the chamber will be too slow to be measured accurately in a reasonable timeframe. The DEQ presently uses two sizes of chamber bodies: 30 liter and 70 liter. It is advisable to have both chamber sizes on hand when setting up a measurement, and it is also advisable to deploy datasondes in the water column.

Equipment and Supplies

- SOD Chamber Bodies Large/Small
- SOD Blank Chambers Large/Small
- SOD Chamber Lids and Closures
- SOD Chamber Battery Packs
- SOD Battery Chargers
- SOD Chamber Datasondes
- Water Column Datasondes
- YSI DM610 (handheld display unit)
- DM610 Battery Charger
- YSI Field Cables
- Hydrolab Field Cables
- Hydrolab Calibration Cables
- Hydrolab Battery Pack
- Spare AA Batteries for YSI Sondes

- External Power Battery for Datasondes
- Laptop Computer
- Floppy Disks
- GPS Unit
- Cell Phone
- DO Membranes
- DO Electrolyte
- Clear BOD Bottles
- Dark BOD Bottles
- Winkler Titration Kit and Reagents
- pH Buffer Kit
- Flow Meter Kit
- 100 Ft Tape Measure
- 30-gal. Plastic Garbage Can
- Buoys
- Mooring Weights
- Rope
- Cable Ties
- Aircraft Cable
- Aircraft Cable Crimps
- Aircraft Cable Cutter
- Aircraft Cable Crimping Tool
- Padlocks
- Tool Kit including:
  - Pocket Knife
  - Wrenches
  - Pliers
  - Screwdrivers
  - Flashlight
  - Volt/Ohm Meter
  - Butane Soldering Iron
  - Butane
  - Rosin Core Solder
  - Duct Tape
  - Epoxy Putty
- When boating add:
  - Boat Keys
  - Anchor with Line
  - Spare Anchor with Line
  - Bailer/Bilge Pump
  - VHF Radio
  - GPS
  - Depth Finder
  - Compass
  - Charts
  - Oars
  - Life Jackets
  - Mustang Suits
  - Throwable PFD
  - Seat Cushions
  - Flare Kit
  - Signal Horn
  - Binoculars
  - Backup Motor
- Gas Can & Hose
- 2-Stroke Oil

Calibration and Standardization

Follow routine datasonde calibration procedures as described in this Manual of Methods. Then set up all datasondes for a 1hr test run in ambient water with a 5-minute recording interval. A plastic garbage can filled with ambient water can be useful for this purpose. Collect Winkler audit samples during the test run. Download the datasondes into a laptop computer and check the data to make sure the precision and accuracy of each instrument is within acceptable QC limits (within +/- 0.3 mg/l of the Winkler results).

Methods

The following procedures are adapted from Murphy and Hicks (EPA Region IV, 1986).

1 Obtain preliminary information about the study area to determine general sediment types and current velocities.

2 Calibrate meters and other monitoring equipment. Set datasondes to record every 5 minutes, and install in chamber mounting brackets.

3 Measure vertical profiles of DO, temperature, and salinity or conductivity. If possible, measure bottom velocities. Near-bottom DO concentrations of >2 mg/l are generally needed for SOD determination. Attempts at measuring SOD rates with ambient DO of less than 2 mg/l must be done with great caution or the oxygen will be depleted in too short a time period. This problem can sometimes be circumvented by deploying the chambers with the lid in place and trapping more oxygen rich water near the surface. However, this method modification is more likely to stir up sediments during the deployment.

4 Check delivery of power and operation of the circulation pump.

5 In deep water, chambers must be deployed by qualified divers. Deploy the blank chamber body and make sure it is free from trapped air bubbles and sediment. Purge the pump, secure the lid, position the chamber upstream of the other chambers, and then turn on the pump.

6 Deploy the measurement chamber body and make sure it is properly seated in the sediment. To achieve a good seal in most sediment, the cutting edge should penetrate 5 cm into the substrate. On coarse or rocky substrates, it may be necessary to install a rubber collar to aid in sealing the chamber. The chamber volumes given in this protocol (30 L and 70 L) are approximate, and for each installation, the volume of the enclosure should be calculated based on the depth of penetration and the chamber area of 0.259 m^2. The pump, plumbing, and datasonde within the chamber displace 1.74 liters, and this volume must be subtracted from the calculated chamber volume. The use of divers reduces uncertainty about the depth of penetration and the chamber's seal. In freshwater, the chamber's seal could be tested by remotely injecting a saturated KCl solution into the chamber and monitoring conductivity.

7 Once the chamber has been properly seated, purge the pump, install the lid, and allow about 20 minutes for settlement of material that might have been resuspended during deployment, then switch on the pump.

8 At the beginning of the test determine ambient DO at chamber level by the Winkler method, and deploy a minimum of two light and two dark BOD bottles alongside the chambers for incubation

during the course of the SOD measurement. Use water column respiration values obtained from the dark bottles as a back up to the blank chamber.

9 Continue the measurement for about 2 hours. At the conclusion of the test, determine ambient DO at chamber level by the Winkler Method.

10 Retrieve chambers and check DO probe calibration and operation of the circulation pump. If possible, divers should check pump operation just prior to termination of the test.

11 Four to six replicate chamber measurements at different locations on the substrate are suggested in the EPA method. Field experience by DEQ staff has shown that three measuring chambers and one blank chamber can be simultaneously deployed by a field crew of 2-3 individuals, plus divers. Therefore, depending on quality control objectives, and equipment and staffing limitations it may be necessary to repeat the measurement to achieve the desired number of replicates. If the SOD test will be repeated, allow the BOD bottle experiment to continue until all measurements have been completed.

Calculations and Data Reporting

It is recommended that datasondes be downloaded in the field to determine if the measurement was successful or needs to be repeated.

Download datasondes and graph DO vs. time in a line graph. Typical SOD rate graphs show an initial rapid drop in DO during the first 20 minutes or so due to resuspension of oxygen demanding materials. Thereafter the DO decay becomes more stable and linear. Use the linear portion of the data set to determine the SOD rate. This can be done graphically or a linear regression line may be fitted to the data. Determine the SOD rate for each measurement chamber, then subtract out any observed decay rate in the blank chamber. If the blank chamber deployment failed, use the DO decay from the dark BOD bottle experiment to determine a water column respiration rate. Individual chamber SOD rates and graphs should be reported separately with ancillary data such as QC results, bottom substrate type, water depth and current velocities, and other field observations. An average SOD rate for the study reach should also be reported.

SOD is calculated according to the following equation (Equation 1):

$$SOD = 1.44\ V/A\ (b1-b2) \qquad (1)$$

Where: SOD = $g/m^2 \cdot day$

b1 = rate of change in DO concentration in measuring chamber ($mg/l \cdot min$)

b2 = rate of change in DO concentration in blank chamber ($mg/l \cdot min$)

V = calculated volume of the chamber (l)

A = area of substrate isolated by measuring chamber (0.259 m^2)

1.44 = constant for converting ($mg/l \cdot min$) to ($g/m^2 \cdot day$)

References

Murphy, Philip J., and Delbert B. Hicks (U.S. Environmental Protection Agency, Region IV), 1986. In-situ Method for Measuring Sediment Oxygen Demand *in* Hatcher, K.J., ed., Sediment Oxygen Demand-

Process, Modeling and Measurement, p.307-322. University of Georgia, Institute of Natural Resources, Athens, Georgia.

AUTOMATED SAMPLERS

Background

Principles

Currently, there are the two types of automated samplers used at the Oregon Department of Environmental Quality; the Sigma 900 (Figure AS-1) and the ISCO 3700 (Figure AS-2). These are just two types of a host of automated water samplers available on the market. Automatic samplers are used to collect composite or grab samples when several aliquots are required at frequent intervals or when a continuous sampling is required. In general, automated water samplers' operate by programming time/flow-based data into the control box to collect discreet or composited samples.

Figure AS-1: Sigma 900 Sampler

Figure AS-2: ISCO 3700 Sampler

In any type of monitoring methodology, the types of required samples should be identified in the sampling protocol. Three distinct types of sampling procedures include (Corbitt, 1989):

1. **Grab Sampling:** a single volume of water is collected at a specified point and time and then analyzed. This method will not always provide the most accurate measurement of the ambient characteristics (i.e. where non-homogeneous flow is present and /or pollutant load varies with time). Typically, grab samples are collected "by hand", but automated samplers have been used in this capacity.
2. **Time Proportioned Sampling:** is a timed sequence of sampling in which an equal volume sample is collected and deposited into a reservoir (either discrete bottles or a single composite container) This is the most common type of sampling with automated sampler.
3. **Flow Proportioned Sampling:** is a type of sampling whereby incremental subsamples are collected, with volumes proportional to flow and deposited into a reservoir (either discrete bottles or a single composite container). This is the most accurate type of sampling with or without an autosampler.

For composite sampling applications, the automatic samplers may be used to collect *time proportional* or *flow proportional* samples. In the flow proportional mode, the samplers are activated by a compatible flow meter. Flow proportional samples can also be collected using an automatic sampler equipped with discrete containers and manually compositing the individual subsamples with volumes proportional to the flow. The various methodologies for automated samplers include (Isco, Inc., 1990):

- **Time-proportioned composite sampling**: In a time based sample, the individual samples are combined-"composited"-into a single container. Samples are collected at equal increments of time.
- **Flow-proportioned composite sampling**: In a flow composited sample, the individual samples are combined into a single container. Samples are collected at equal increments of flow volume, as measured by a coupled flow meter.

When a differentiation between single sampling events is required (i.e. separation of specific samples during one event period; also called discrete sampling) the following options are available when using automated samplers:

- **Time-paced sequential (discrete) sampling**: samples are collected at equal increments of time. Each bottle receives one sample. (Please see multiplexing information below for additional applications of multiplexing)
- **Flow-paced sequential (discrete) sampling**: samples are collected at equal increments of flow volume, as measured by an associated flow meter. Each bottle receives one sample. (Please see multiplexing information below for additional applications of multiplexing)

Both time paced and flow-paced samples can be multiplexed. Multiplexing places more than one sample in a bottle at different sample events (called "sample per bottle") or places a sample in several bottles at the sample event (called "bottles per sample").

Scope and Application

Automated water samplers are acceptable for use in several environments, which include:

- Fresh water
- Salt water
- Streams
- Lakes
- Wastewater effluent
- Mixing zones

Automated water samplers were originally designed to collect samples in a variety of harsh environments, namely wastewater applications, where the extreme type of environment can damage the unit. Applications in the above environments could include sedimentation studies, bacterial sampling (rinse cycles and holding time protocols provide significant hurdles), metals monitoring, and various types of organic constituent monitoring (users should think about container and preservation requirements for each of the parameters to be sampled when using automated samplers; some analyte(s) require specific containers and preservation methods). Generally speaking, automated samplers can be used in virtually any study where consistent time or flow-based samples of consistent volume size are required over an extended period.

Technical Specifications & Installation

Effective sample depths should not exceed approximately 27 feet when using an autosampler. Samples collected beyond this depth may not be of an adequate volume for a representative

sample due to pump head limitations. Refer to specific owner's manual for maximum head pump distance.

Temperature specifications for the automated samplers employed by ODEQ are rated as follows (**Table 3**):

Table 3 Automated Sampler Temperature Specifications

Model	General Operation	LCD Display Operation	Storage
Sigma 900	0 to 50°C	-10 to 70°C	-40 to 80°C
ISCO 3700	0 to 50°C	NA	-20 to 60°C

In addition to the above temperature specifications, consideration should be given to evening temperatures when samplers are exposed to lower temperatures (at or below freezing in some cases) during the colder months of the year. Care should be given to insulate the sampler and all of its components to avoid freezing. The opposite is true when samplers are exposed to high temperatures. Procedures should be taken to provide adequate refrigeration (i.e. adding ice in the base of the unit) to adequately preserve the collected samples.

Automated samplers should also be secured and protected when left unattended. Proper security includes protecting the integrity of the samples and the sampler power source. Users should take whatever steps necessary to prevent tampering with equipment. A lock or custody seal may be placed on the sampler to detect tampering. This does not, however, prevent tampering with the sampling line (either by humans or animals). Specific operating instructions, capabilities, capacities, security and other pertinent information for automatic samplers are included in the respective operating manuals.

Equipment and Supplies:

- Sampler base with correct sample containers depending on sampling protocol (i.e. glass or plastic bottles, composite or sequential containers refer to QAPP or SAP for specific requirements)
- Center Section of sampler
- Cover or Top Section of sampler
- Sample tubing
- Peristaltic (pump) tubing
- Power: When AC power available, use gel AC power pack (or equivalent) with sampler equipment. When there is no AC available, use stand alone battery packs (Ni-Cad, Gel, or Deep Cycle Marine Batteries). Note: depending on sampler frequency, battery life can vary greatly. Develop a maintenance scheme to attend to spent stand alone batteries.
- Cooler (for collected samples) and ice
- Data collection sheets
- Security cables and padlocks

Methodology

The technique for using an automated sampler will vary depending upon the sampling frequency and volume requirements for specific analytical parameters. Numerous program examples are

available within the respective user's manual. Considerations should be given to location, type, frequency and duration of sampling to be done in the field. Descriptive flow charts outlining the programming sequences for both the ISCO 3700 and Sigma 900 auto samplers are also located in their respective owner's manuals.

Sample location should be representative of the area being monitored. Stream flow should be well mixed, accessible and representative of ambient conditions. Additionally, samplers should be placed in a horizontal and level position to ensure sample deposition in the sample bottle. Again, the frequency and duration of the sampling will vary dependent upon the requirements of the project. In all cases though, samples collected should be proportional to the actual pollutant load of the water body (Corbitt, 1989).

Regardless of the type of automated sampler and sampler application, automatic samplers should meet the following requirements (American Sigma, 1997):

1. Sampling equipment must be properly cleaned to avoid cross-contamination which could result from prior use.
2. No plastic or metal parts of the sampler shall be exposed to the water or wastewater stream when parameters to be analyzed could be affected by these materials.
3. The automatic sampler must be capable of providing adequate refrigeration during the sampling period. This can be accomplished in the field by using ice in the sample bottle cartridge.
4. The automatic sampler must be capable of collecting a large enough sample volume required for the chemical analyses.
5. The individual sample aliquot should be at least 100 milliliters in volume. Samples should be collected at a rate of approximately two aliquots per hour. (Collection rates will vary with sampling needs). The suggested sample volumes are based upon the average of sample volume accuracy (typically the greater of +/- 10% or +/- 20 milliliters) and sample volume repeatability (typically +/- 10 milliliters). It is most always better to have more sample than not enough sample.
6. The automatic sampler should be capable of providing a vertical lift (pump head) of at least 20 feet, and the sample program should be adjustable for volume, since the volume is a function of the pumping head.
7. The pumping velocity must be at least 2 ft/sec to transport solids and not allow solids to settle.
8. The intake line leading to the pump must be purged before each sample is collected (typically called "sample rinse").
9. The minimum inside diameter of the intake line should be 1/4 inch.
10. An adequate power source should be available to operate the sampler. Facility electrical outlets or 12V deep cycle marine batteries may be used if long-term sampling is to occur (typically, voltages below 10V will run program but WILL NOT turn pump).

Deployment periods for automated water samplers are suggested from a minimum of 24 hours (grab samples may be more efficient for monitoring periods under 24 hours) to as long as the user defines, provided maintenance and calibration are conducted on a regular basis. Common items

that need attention during extended deployments include unit desiccant, sample tubing, pump tubing, and battery charge.

Analyte Collection Considerations

Inorganic Parameters

Conventional sampling includes all inorganic parameters (e.g., BOD5, TS, TSS, COD, nutrients, and Metals) that can be collected using an automatic sampler. New tubing shall be used for each sampler installation. Installation procedures include cutting the proper length of tubing, positioning it in the surface water stream (parallel to flow in a well-mixed, representative area), and programming the sampler (since programming protocol varies between models, refer to owner's manual for specific procedures). Protective gloves should be worn to reduce exposure and to maintain the integrity of the sample.

When an automatic sampler is used for collecting samples for metals analyses, the entire sampler collection system should be rinsed with organic/analyte free water, and an equipment blank should be collected (typically blank samples should be collected at a rate of one blank per day or at a rate of 10% of the samples collected per day, whichever number is greater). Approximately one gallon of rinse water should be pumped through the sample tubing into the composite container and discarded. Nitric acid must be added to the metals blank container and collection bottles for proper preservation. The sampler may then be positioned in the appropriate location and the sampler program initiated. If the sampler tubing is attached to a metal conduit pipe, the sampler intake tubing should be carefully installed upstream and away from the conduit to prevent metals contamination. This can be accomplished by clamping the tubing upstream of the conduit using clamps and wrapping the submerged portion of conduit pipe with a protective barrier (e.g., duct tape).

Extractable Organic Compounds, Pesticides, and PCBs

When an automatic sampler is used for collecting samples for the analyses of extractable organic compounds, pesticides, and/or PCBs, the installation procedures include cutting the proper length of new Teflon® tubing, rinsing of the entire sampler collection system with organic/analyte free water, and collection of appropriate blanks for organic compounds analysis. For the organic/analyte free water rinse, approximately one-half gallon is initially pumped into the composite sample container(s) and discarded. An additional one and one-half gallons are then pumped into the composite sample container for distribution into the appropriate blank container. Finally the collection tubing should be positioned in the stream and the sampler programmed and initiated.

Regardless of the type of analyte, the sampler should be programmed to collect a minimum of 100-milliliter aliquots at a frequency that provides a representative sample and enough sample volume to conduct all required analyses. Additionally, one equipment blank sample should be collected at a rate of one blank per day or at a rate of 10% of the samples collected per day, whichever number is greater. When collecting flow-weighted samples (flow-proportional samples), the sampler should be programmed to collect a minimum of 100 milliliters for each sample aliquot with the interval pre-determined and based on the flow of the monitored stream (i.e. for a stream with a average discharge of 240 cfs, a sampler could be programmed to collect samples once every 5 cfs during a 24 hour period yielding approximately 2 samples per hour). The sampler would collect approximately 48 samples during a 24-hour period).

At the end of the compositing period, the collected sample should be properly mixed and transferred into the respective containers, followed by immediate preservation, if required.

Calibration /Standardization

Programming includes calibrating sample volume, multiplex amount, head height, rinse cycles, and meta-data (e.g., time and flow for sample triggering). Calibration of automated samplers can be either automated or manual. User should refer to user's manual for specific calibration procedures.

To insure proper operation of automatic samplers, and thus the collection of representative samples, the following maintenance and calibration procedures should be used and any deviations should be documented in a logbook:

1. Prior to being used, the sampler operation should be checked by field personnel. This includes operation (forward, reverse, automatic) through three cycles of purge-pump-purge; checking desiccant and replacing if necessary; checking the power source to be used with the sampler; and repairing any item if necessary.
2. During each sampling expedition, prior to initiating the automatic sampler, the rinse and purge-pump-purge cycle shall be checked at least once. The pumping volume should be checked at least twice using a graduated cylinder or other calibrated container prior to initiating the sampler. For flow proportional sampling, the flow pacer that activates the sampler should be checked to insure that it operates properly.
3. Upon return from a sampling expedition, the structural integrity of the sampler should be examined and repaired, if necessary. The desiccant will be checked and replaced if appropriate. The operation (forward, reverse, automatic, etc.) will be checked and any required repairs will be made and documented. The sampler will then be cleaned (pump, control box, base, sample probes, etc). The automatic sampler should be checked against the manufacturer's specifications and documented whenever one or more of the sampler functions appear to be operating improperly.

Calculations and Data Reporting

There are no specific calculations associated with using an automated sampler. Considerations should be given to the sample frequency, volume and multiplex settings when reporting samples for log-in. Sample volume calculation worksheets are available within the respective owner's manuals.

Data reported to the lab shall have indications regarding the type of sample collected through the automated sampler (i.e. time frame of represented sample and whether or not the samples given to the lab are composited samples or discrete samples). Please see user's manual for additional information regarding calculations and data reporting.

References

American Sigma, 1997. Sigma 900 Standard Portable Sampler Operations and Maintenance Manual. American Sigma.

Corbitt, Robert A., 1989. Handbook of Environmental Engineering.

Isco, Inc., 1990. 3700 Portable Sampler Instruction Manual. ISCO, Inc.

US EPA, Region 4, 1996 (includes 1997 revisions). Environmental Investigations Standard Operating Procedures and Quality Assurance Manual. US EPA, Region 4.

CONTINUOUS MONITORING DATA QUALITY ASSURANCE

Background

This section deals with quality assurance and control (QA/QC) procedures specific to continuous data generated by data loggers. General data QA/QC is covered in the Quality Assurance and Data Management Sections of Chapter 2. Continuous data requires special considerations because field staff process raw continuous data before submitting the data to the sample tracker. This section describes the procedures for processing continuous data and how to prepare the data for QA/QC review. Equipment of concern includes:

- Vemco Thermistors
- Onset Thermistors
- Unidata Loggers
- Hydrolab Datasondes
- YSI Datasondes
- Greenspan Datasondes

Continuous monitoring equipment generates large amounts of raw data that are impractical to verify on a point-by-point basis. For example, a typical 3-day Hydrolab datasonde deployment will generate about 1,200 data points. It is the responsibility of the field staff to review the raw data, compare it to field audits and prepare QA/QC reports that summarize the data for submittal to the sample tracker. In the QA/QC report, field staff grades data based on comparison to audit values and behavior of the data over time.

Sampling error can be found with variation in equipment, time and space. If the equipment is properly maintained and sampling has occurred in the recommended period and place, any discrepancy observed needs data qualification. If a reasonable cause is not found to explain audit/instrument disagreement, the data is suspect. If it is obvious that either the audit value or the instrument values are in error, then the erroneous data will be voided immediately.

Criteria for Establishing Confidence Intervals for Data

Laboratory staff has agreed that the criteria for establishing appropriate levels of confidence for audit data must be based on a large set of audit/instrument comparison values. A large data set of comparison values more clearly indicates that point at which continuous monitoring data can be considered acceptable or not acceptable. Data Quality Levels and data validation criteria are defined in DEQ04-LAB-0003-QAG, found on QNet and can also be found as Appendix A in Chapter 2 of MOM's.

Table 4 describes criteria establishing whether the audit instrumentation or reagents are of known quality for checking continuous monitoring equipment. Instrumentation or reagents not meeting above criteria should be recalibrated, repaired or replaced to meet criteria, in lab and/or in field where necessary. If these measures fail, the instrument or reagents should not be used. Meticulous field notation should be kept regarding field re-calibration.

Table 4 QA/QC Criteria for Auditing Instrumentation or Reagents

(To be performed in laboratory to insure accurate, reliable equipment)

Water Temperature (°C)	± 1.5 °C in field, comparable to a NIST-traceable thermometer; or ± 0.5 °C in lab (controlled warm and cold water baths)
Dissolved Oxygen (mg/L)	Sodium Thiosulfate reagent should be ± 0.1 mg/L on standard solution, Winkler titration (see Dissolved Oxygen section of MOM's for methodology)
pH (SU)	± 0.05 SU, standardized to ambient air temperature; minimum 2-point calibration check with pH buffer solutions and/or LIS (low ionic strength) solution in range of values expected.
Conductivity (µmhos/cm)	± 7% difference of Actual reading vs. Standard solution value • Use NIST Traceable/Lab certifiable standard solution • Check values between 5%-7% Actual reading vs. Standard solution reading

What is required for each level of data quality?

The following decisions apply to temperature and multi-parameter data logger monitoring data.

- (A) Level data must have pre- and post- deployment accuracy checks and at least two field audits. The accuracy criteria apply to the pre- and post- accuracy checks. (A) Level data must be bracketed by field audits that meet the criteria. Interpretation of this is that the pre- and post- deployment accuracy checks must be water bath checks for temperature loggers, and pre- and post-calibration checks on datasondes.

It should also be noted that even if the data passes all QA/QC criteria for (A) level the entire data set still needs to be reviewed for other obvious problems. A good example of this is a probe that may have been exposed out of the water for some portion of the deployment. Even though this unit may have passed pre and post checks and audits, by looking at the magnitude of the diurnal temperature range it is easy to spot if the unit was out of the water for some period of time and that data should be voided.

- In order for data to be Grade A, the QAPP should be reviewed and approved by WA or QA/QC personnel at ODEQ. Program/Regional staff should be able to review and approve QA/QC plans. Lab staff could prepare some guidance, including a check list for reviewing and approving plans.
- Data that has pre and post deployment accuracy checks but no field audits, OR data that has field audits but no pre and post deployment can **at best** be graded (B). (Data with field audits only, the field audits for temperature must be done with a NIST-traceable thermometer and/or audit instrumentation or reagents that are of known quality for checking continuous monitoring equipment; this suffices for accuracy check for B level quality).

The data quality matrix is guidance for evaluating data quality and should not be considered the only thing used, or the final word in evaluating data quality.

What are the uses of the data?

Level A could be used for regulatory purposes such as 303d listing or delisting, TMDL model development, etc.

Level B could be used for regulatory purposes, but this decision should be based on best professional judgment. Examples of factors that should be considered are:

1. The precision and accuracy of the data with respect to the magnitude of the difference from the standard.
2. Supporting data such as the pre- and post-deployment checks, other collaborating studies, and a careful review of the data to determine if it looks "reasonable" based on professional judgment.

Level E data should not be used in regulatory decision making.

Who will perform the statistics?

The data submitter should perform the statistics. DEQ may choose to review that work (particularly if we are considering using B data), or may offer to provide that work at our discretion (as we are doing for some watershed councils).

Statistical summaries should be performed on each data set. Cursory statistical analyses of outliers, out-of-range, and extreme values, should be reviewed for statistical significance and representativeness of data set and site conditions. Data points outside the expected and/or "normal" range of values should be graded with **Best Professional Judgment (BPJ)**. For example, values outside what normally would be expected for pH, but verified by field audits (initial grading system (A-E)) and observed site conditions (i.e. high algal contents), would be graded **BPJ+**. Data points not verified by audit data or data that is suspect due to human or instrumentation error, but passes initial grading (A-E), would be flagged with a **BPJ-**. Data points with BPJ+ flags will be kept as valid data and used in the database for regulatory or development schemes. Data points with a BPJ- flags would not be deleted from the data set, but should be treated as invalid, erroneous, or problematic measurements and not used for any type of regulatory or development scheme.

Required Software

The DEQ Lab has developed software to assist in the processing of large amounts of continuous data. The software loads continuous data and audit data into an Excel workbook, compares the audit data to the appropriate raw data, and generates summary statistics and graphs of the data. This section gives a general description of how to use the software and identifies special considerations for using the software to grade data.

Processing raw continuous monitoring data for data review, comparison to field audits and generation of data summaries can be done using MS Excel macros developed at the DEQ Lab. You will save significant amounts of time using these macros if you are careful to prepare all data files appropriately and follow the procedures for running the macro.

Although the intention of the Excel macro was that it could be applied to all continuous monitoring equipment, some specification has been necessary. You may access the Excel macros in the Watershed Assessment shared directory \\Deqlead01\wqm\forms\Continuous_Monitoring_Utilities under the names:

Audit_Master – Used to present all audit information in a way that subsequent macros

will identify.

HYDROSTAT - Specifically set up to process multiple Onset or Vemco thermistor files unattended.

Flowpro_00_6.xls (or latest version) - A separate macro for calculating discharge based on flow measurements and channel geometry.

DIURNAL_LOADING_TEMPLATE - The generic macro used for datasondes or thermistors to run one raw data file at a time.

Periodically, programs are upgraded or calculations modified to more accurately display data and statistics. Using the latest version of the software is recommended. Download the macro from the network to your computer's hard drive and run the samples. Downloading the macro to your hard drive will speed up the processing time and will assure you do not use an old copy of the macro that may contain some errors. Contact the DEQ Laboratory if you have any questions.

Methods

The Laboratory's Technical Services section is largely responsible for data management. Sample tracking, LIMS/LASAR development and management, and related documentation and support are among the services provided by this section. Contact Technical Services for the most current information regarding data management.

Instructions for the use of Hydrostat are included as a separate worksheet in the Excel file. The basic steps are: (1) prepare electronic text (.txt) files; (2) Load files into Hydrostat; (3) review the files; and (4) save/print the files. Each of these steps is discussed below.

Prepare Electronic Files

You will need to create two different file types—audit Excel sheets and raw data text files. Each continuous text file will have an audit sheet needed to create .csv upload files. The "AuditMaster" Excel file should be the most up-to-date version of the audit sheet (Temp or Multi-parameter). Your audit sheet tab name should match the text file name. One audit sheet is used to record the audit information for a single probe deployment. You will be asked to enter:

- Project Name (optional)
- Site Name:
- USGS Quad Names and Numbers (optional)
- LASAR#
- Site Description (optional if you have a LASAR number)
- Site Latitude
- Site Longitude
- Elevation (optional)
- Temperature Logger ID (or data logger name)
- Date of Battery Installation (optional)
- Data File Name (optional)
- Depth (optional if deployed at a known depth for depth profiles)
- Initials (your initials)

Five-digit LASAR site numbers must be obtained from LASAR and entered for the macro to work using this audit sheet. Thermistor audit sheets must include pre- and post- deployment information for grade A data. Both thermistor and multi-parameter audit sheets need audit dates and times at the beginning and end of the deployment. If an audit is missing, report date and time the unit was either deployed or removed without an audit value. **Use the mm/dd/yy format for date and a colon to separate hour and minute values using the military, 24-hour time format. Do not format Excel date cells!**

A simple way to prepare audit sheets is to place all audit sheets for a particular deployment into a single workbook. Each worksheet in the workbook contains an audit sheet for one probe with the sheet named accordingly. The names of tabbed audit sheets within a workbook should contain no spaces or punctuation and are case-sensitive. When you use Hydrostat to join and process the audit sheet to the raw data, the macro will ask you to navigate to the workbook and worksheet locations.

The second electronic file type you need is the raw data text (.txt) file. The software associated with each type of continuous monitoring equipment determines many of the specifics of the formatting for these files. Although each download process will be different, you should select the following options for download when given a choice.

- File Format- text file (.txt)
- Date Format- mm/dd/yy (example 03/02/01 for March 2nd, 2001)
- Time- include colons between hour:minute
- Temperature- Celsius
- No periods in file name except to separate name from the "txt" extension (Example: raw_data_9185.txt)

DIURNAL_LOADING_TEMPLATE.xls is used for uploading Multiparameter probe data. Cut and paste information into the appropriate columns and place the file in \\DEQLAB3\Data2LASAR\WQM\CONTINUOUS_UPLOAD_FILES\DIURNAL_MULTIPARAMETER_DATA. Permitted individuals run an upload macro on these files to load the data into LIMS. Check with the WA section manager for further information.

Load Files into Excel Macro

Hydrostat can process multiple files in batch and save the output. Once all of your raw data temperature files and audit files are completed and saved in the same folder location you can enter Hydrostat. To run Hydrostat save the macro to your hard drive and have the raw data and audit files saved together in the same folder as mentioned above. Keeping all files on your hard drive will speed up the processing time.

Once you have correctly filled in all information on the "Auto_Info" worksheet in Hydrostat, including audit name, raw text file name, audit sheet tab name, and saved file name, you are ready to process files. On the Menu worksheet tab, select the correct radio button ("Vemco" or "Onset") for your units. Click on the "Run Auto List" button to start the macro. The amount of time required to process one file will vary based on the speed of the computer and the memory available. The recommended computer speed is > 500 MHz with an internal memory of at least 100 megabytes.

Review Files

The initial output of the macro should be viewed only as a convenient way of reviewing your data to assign grades. The macro follows a very basic process and you will need to identify errors made in its grade assignment. In general you will be looking for extraneous data that was not properly graded by the macro, or data that was accepted as grade A or B but which behaves inconsistently with expected patterns when viewed graphically.

- Extraneous data comes from dates and times when the data logger is not in the sample medium. Identify extraneous data points by comparing the first and last grade A or B data points on the Data worksheet with the time of the audits on the audit sheet. Data outside the window of audited times should be graded D (to be deleted).
- Examine the graphs to make sure the data does not behave inconsistent with expected behavior. Equipment emerging from the water, meter malfunction or tampering may result in unrepresentative data that should be appropriately graded. If in doubt about when a logger may have come out of the water, a 1-day additional buffer is deleted from either side of obvious data errors.
- Make sure to review statistical temperature data for errors resulting from the macro using partial days to compute statistics.
- Incorrectly entered audit values will result in improper grading of data. Audit points are displayed on the graphs with their corresponding grade A error bars. You may double check the audit values by comparing the electronic audit sheet to your field data sheets.
- Dissolved oxygen percent saturation values that require an elevation correction factor may need to be calculated manually for the raw data. Observation of % Sat audit values on the graph should correspond to DO mg/L values. Calculate % Sat for the audit values by hand and compare these values to the numbers calculated by the macro to find any problems. NOTE: Data is not graded based on percent saturation values.

Use Hydrostat after running the files to review. Make changes by entering override instruction on the audit sheet tab in Hydrostat. Describe grade changes made and why before committing changes by using the 'OVERRIDE Current File' button. This button also saves changes to the saved .csv file.

Save/Print Files

Use the "SAVE Changes" button to save any meta-data changes (LASAR number, Site Name, etc.) that are not grading overrides.

Hard copies of the data should be submitted to the sample tracker with a completed report sign-off sheet and a yellow QA request sheet listing all sites and units included. Saved file folders (.csv) should be placed in the appropriate folder for upload. File folder names must contain both the Sampling Event number (case number) and the Fund Code for the deployment. DO NOT place individual files in this location unless it is named with Sampling Event and Fund Code.

References

Oregon DEQ, February 2009. Data Quality Matrix Version 3.1, DEQ04-LAB-0003-QAG, Oregon DEQ Laboratory, Portland, Oregon.